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THE COLLAPSE DURING CONSTRUCTION OF A REINFORCED-CONCRETE BUILDING OF THE EASTMAN KODAK CO., ROCHESTER, N. Y.

On Friday, Nov. 21, 1906, a portion of a new building being erected at the works of the Eastman Kodak Co., Kodak Park, near Rochester, N. Y., collapsed, killing two men outright and injuring several others, two of whom died shortly afterward. The building was of the Kahn type of tile-and-reinforced-concrete construction, and was being erected by the Concrete Steel and Tile Construction Co., of Detroit, Mich., who also designed it. An investigation was instituted by Coroner Thomas A. Killip, of Monroe County, who called as expert advisers County Engineer J. Y. McClintock, M. Am. Soc. C. E., and Mr. J. Herbert Grant, M. Am. Soc. C. E., both of Rochester. Messrs. J. M. Brazill and H. Pierce, deputy fire-marshals of Rochester, assisted in the examination of the ruins. The Coroner's verdict has just been rendered, and its most important parts are printed below. We are able at the same time to present a number of photographic views illustrating the wreck, together with sketches and notes taken from Mr. McClintock's technical report to the Coroner.

The general view of the wreckage herewith shows that only part of the building collapsed. The eastern end only was affected. Fig. 2, a ground plan with sections, locates the collapse more definitely. The structure has three stories for part of its area; the main floor is 10 ft. from the ground in this part, and 14 ft. elsewhere. The total height from ground to roof is about 28 ft. All of it was of regular column, girder and slab construction, without unusually long spans. The columns, floors and roof were of reinforced concrete, floors and roof having hollow tile 12 ins. wide incorporated in rows separated by concrete beams 4 ins. wide, reinforced with Kahn bars. The columns were reinforced with Kahn bars and some plain round rods. The exterior walls were of brick. At the time of the collapse, the framework of the building and much of the exterior brickwork was completed, and waterproofing was being put on the roof.

The extent of the collapse was as follows: The roof and its supporting columns fell for a space about 53 ft. by 89 ft. The mezzanine floor, below, gave way over an area 21 ft. (one panel) by 45 ft. The main floor stood the shock of the falling debris without failure, except that a hole through it about 2 ft. square was made by the end of a falling girder. The view Fig. 3 shows that the fallen floors broke up into a general wreck-heap of tile, concrete and steel rods, though large parts of the roof remain attached to the standing part and hang down in strips (Fig. 1 and Fig. 5). A large piece of the wreckage is seen in Figs. 4 and 5, showing a roof-girder (37-39) which split off from its far end and dropped bodily, breaking in two when it struck the mezzanine floor at Col. 38; the nature of the fractures in this girder is interesting.

A case of a column which fell almost undamaged is seen in Fig. 6, showing Col. 30, an east wall column. The reinforcing rods at the right-hand end of this column are flush with the concrete, showing that the column had no anchorage to the floor below. The rods projecting from the left-hand end were bedded in the roof-girder, which tore away from the column. In Fig. 7 is a column which, though badly shattered, still has its roof-girder attached.

An examination of the ruins shows many evidences of defective workmanship and poor concrete. In the undamaged portion of the building, adjoining the collapsed area, the case shown in Fig. 8 occurs. The lower girder, against which the ladder rests in this picture, is part of the main floor at 10 ft. above ground, while the girder above this supports the main floor at 14 ft. above ground. In the side of this upper girder is a crevice or slot some 6 ft. long, into which one can thrust the hand and feel the reinforcing bar. Evidently, in placing this bar it did not lay solid on the concrete below, and when the form was filled up the new concrete did not flow around the bar, thus leaving the long hollow space and correspondingly weakening the bond between steel and concrete. The view at Col. 45, Fig. 9, portrays the porous condition of the concrete in column and mezzanine floor girder, and (in the original) shows clearly that the column had been smoothed up with mortar to some extent after the forms were removed. Porous concrete is also evidenced in some of the other views, for example Fig. 12.

GENERAL VIEW OF COLLAPSED PART OF NEW EMULSION BUILDING, EASTMAN KODAK CO., ROCHESTER, N. Y., LOOKING SOUTHWEST.

The following is extracted from Mr. McClintock's report to the Coroner:

Many of the posts show a horizontal joint of sawdust and shavings and paper. In Col. 2 at the level of the mezzanine floor I thrust in my knife-blade 2 ins. deep. In Col. 37 at the level of the mezzanine floor there is a

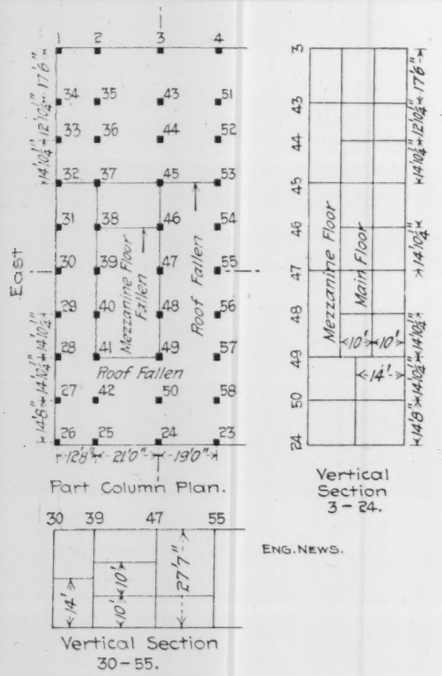


Fig. 2. Plan and Sections of Part of Emulsion Building, Showing Arrangement of Framing and Extent of Failure.

joint of sawdust and shavings, horizontal, nearly if not quite through the section, into which a knife-blade was thrust 2½ ins. easily.

In the north face of Col. 37 [shown in Fig. 10 Ed.] there is embedded a piece of wood showing 5¾ ins. wide by about 13 ins. long, and probably 2 ins. or 3 ins. thick, set up at an angle of about 45° so as to reach clear across the face of the post, apparently dropped into the wooden form along with the shavings and sawdust before the concrete was put in above the mezzanine floor. In the same column below the mezzanine floor the concrete is so poor that I dug into it with a small stick nearly 2 ins. in one spot.

In many places the steel bars show at the surface of the girders on the side.

The girder from Col. 2 to Col. 3, although in the face of the wall, bulges out so as to be deformed, apparently due to carelessness in bracing the forms.

The fact that the main floor resisted the great shock of falling girders, posts and roof, without appreciable injury, indicates that in general the design is satisfactory. The only place broken in the main floor is where the roof-girder between columns 49 and 24, which spanned 28 ft. and sustained 560 sq. ft. of roof, slipped off from its bearing on 49 while still being held up by 24, and dropped one end 14 ft. and still stands in its leaning position, although of course the attached roof was shaken off.

The general condition of the building indicates that the cement was good and that ample time was given for setting before removal of woodwork.

In Col. 47, the upper portion, about 7 ft. long, was of such poor concrete that we easily picked off with the fingers the upper 2 ft., and could crumble most of it in the fingers. I afterwards concluded that this concrete was disintegrated by the wrenching off of the roof girder. The lower portion was pretty well covered up with debris, but appeared to have settled down in its own location by breaking. We afterwards dug down and exposed this as shown in Fig. 11.

I saw many places in posts and girders where the concrete was not filled with mortar, and had the open texture of a pop-corn ball, indicating that it was put into the molds in too wet a condition.

The cinder concrete on the roof has the characteristics of earth rather than concrete.

In many cases the steel bars in girders do not connect or overlap over posts.

The fallen posts show that there was no connection of the steel bars in the part of a post above a floor and below, and there are no dowels.

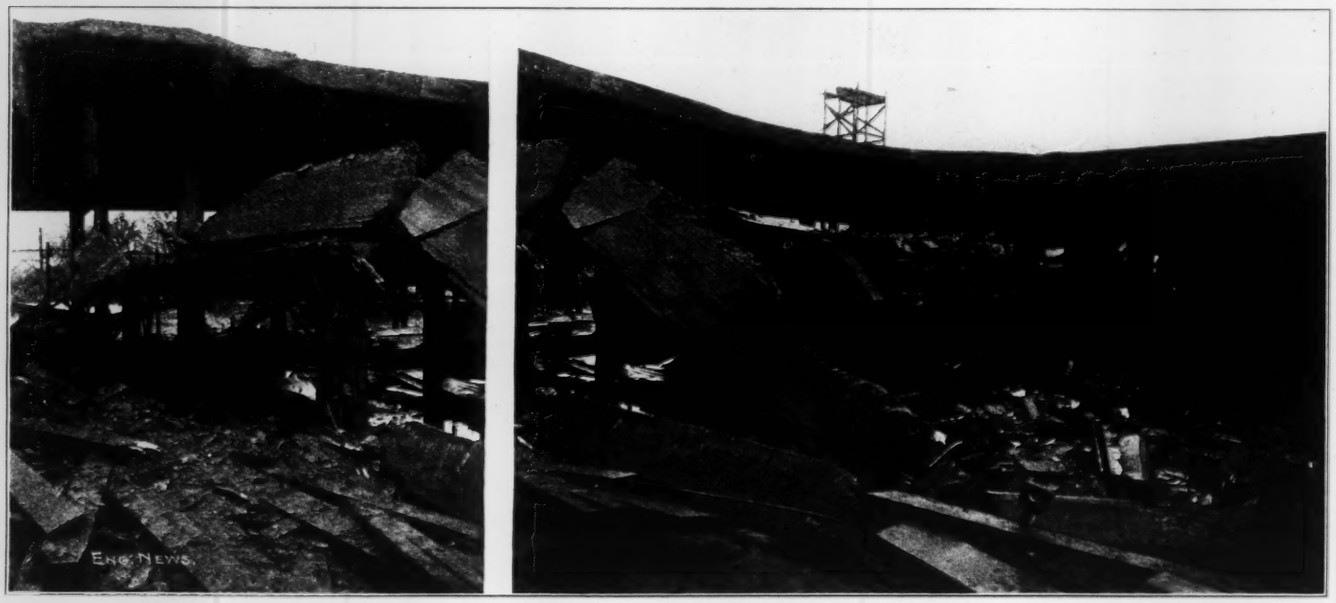
The condition of the wreckage indicates almost (if not quite) with certainty that Col. 47 failed first, and below the mezzanine floor.

The report states that the stone used for making concrete appeared to be of good quality, ½ to 1-in., with some screenings left in; that none of the sand was left on the site, but that the sand-pile location gave every opportunity for getting dirt in with the sand and that some of the crumbling concrete indicates dirty sand in spots.

There was no question raised as to the sufficiency of the shoring. The concrete of that part of the roof which failed was about 17 or 18 days old. The concrete of Col. 47 was about three weeks old.

The case of this column, which Mr. McClintock's report and the verdict of the Coroner charge with causing the collapse, merits further attention. The appearance of this column in the wreckage is to be seen in Fig. 11, a view looking south. The conical end in the immediate foreground of the picture is the lowermost part of the column discoverable. Measured by the length of the protruding bars, there was about 4 ft. of column below this point, and that length of 4 ft. crushed to pieces, bending the bars up as shown. Directly above the bar which bends up in U-shape from the conical end may be seen three short ends of steel rod projecting about 2 ins. above the surface of the main floor; these are three of the four rods com

FIG. 3. VIEW OF WRECKAGE ON MAIN FLOOR, LOOKING NORTHEAST.



FIGS. 4 AND 5. ROOF GIRDER BETWEEN COLUMNS 37 AND 39.

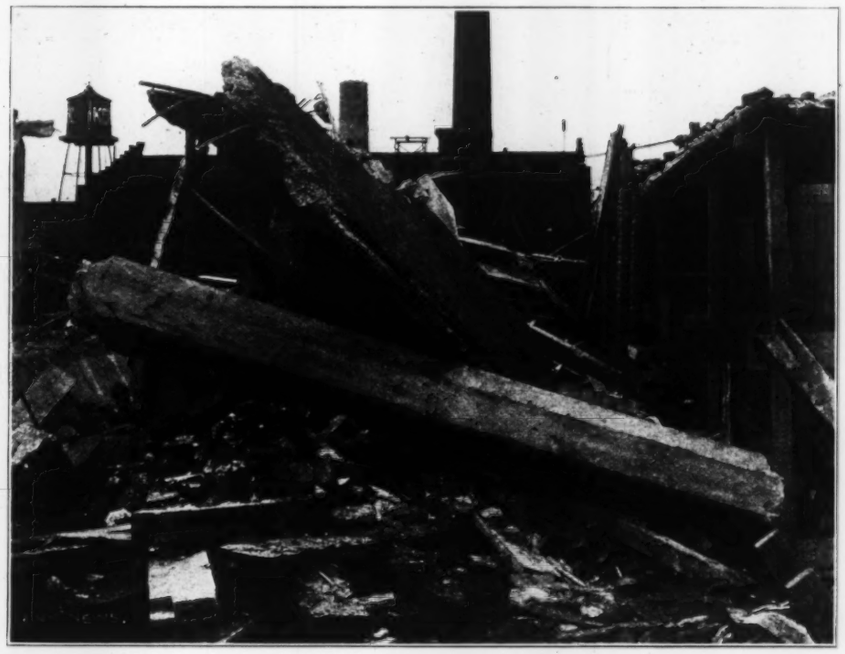


FIG. 6. COLUMN 30 (EAST WALL) FALLEN IN.

ing up from the column below, marking the exact location of Col. 47. The 2-in. projection apparently represents the amount of concrete eroded from the floor by the grinding action of the crushing column. Across this lower fragment of the column (at the left of the picture) lies a part of the mezzanine floor girder which was supported by the column; it fell 8 ft. and is only 9 ins. out of its original line. The girder W showing in the lower right-hand corner is the roof-girder supported by Col. 47. It fell 17 ft. and turned on its side and is only 2 ft. out of its original line. This girder is still attached to the top part of the column, which shows in the middle of the picture and which is itself connected with the lower part of the column by four badly-crumpled Kahn bars. The sketch Fig. 13 (in which girder D is not shown, however) will help to make this clear. A restoration of the column and its attached girders is depicted in the sketch Fig. 14.

The working blueprints show that Col. 47 was to be 18 × 18 ins. to a point 4 ft. above the main floor, and thence 12 × 12 ins.; but it was built 12 × 12 ins. all the way down to the main floor. The column was designed to have four $\frac{3}{4}$-in. rods from main floor to mezzanine, and four Kahn bars from main floor to roof. But only the four Kahn bars were put in; the four round bars additional were omitted. On the other hand, the nearby column 46 shows, on one side where it is broken away, the ends of three bars, indicating eight bars in the column, although only four are called for by the plans. It is possible that these four supernumerary bars are the ones which should have gone into Col. 47.

FIG. 7. A GIRDER AND ATTACHED COLUMN IN THE RUINS.

The near end of the inclined girder in background, which is the roof girder supported by Columns 49 and 24, fell 14 ft. and broke the only hole in the main floors.

The report wherein the above observations are noted gives a computation of loads on the column in question. Summarized it is:

Dead Load:	Lbs.
Roof	50,778
Mezzanine floor	16,227
Roof Girder W	10,500
Mezzanine Girder D	5,190
Column 47	1,950
	84,645

As the area of the column section was 142 sq. ins., this gives a dead-load compression of 596 lbs. per sq. in. But with 1.6% of steel, as in this column, and assuming $E_s \div E_c = 10$, the permissible average stress with 450 lbs. per sq. in. on the concrete would be only 522 lbs. per sq. in. In other words, the dead load alone exceeded the permissible load on the column as built, provided the dead load were central. If the weights of roof and floor-slabs be computed as eccentric loads,* with a mean eccentricity of 1½ ins., the maximum dead-load compression is 950 lbs. per sq. in. The live-load stress, with 40 lbs. per sq. ft. on the roof (waterproofing and snow) and 100 lbs. per sq. ft. on the mezzanine floor, computed as a central load, would be 266 lbs. per sq. in. additional.

Fig. 9. Column 45, Roof Girder Torn Away.

Column 37 is beyond, and Column 32 in the extreme background.

The expert report to the Coroner concludes that on account of these high stresses the design was defective; that the variations from the drawings show faulty construction; and that the weak spots in the concrete, the honeycombed character of the concrete in the lower part of many columns, and the presence of leaves, sawdust, shavings and large blocks of wood in the concrete so as to impair its strength materially, show negligence in construction.

The verdict of the Coroner is in substance as follows:

The building was estimated to cost $34,000, and was being built by the Concrete Steel & Tile Construction Co., of Detroit, Mich., under what is known as "a cost plus a fixed sum" contract, wherein the owner, the Eastman Kodak Co., paid for the materials and labor, bought with its approval, and approved the detail plans and kept control of the construction, and was to pay to the contractors the sum of $3,400 upon the completion of the building within sixty days from date of approval of the detailed plans to be furnished by the contractors, conforming to general plans made by the owner.

At the time of the accident the shell of the building was completed except that the face walls, which were of brick, were being built; the water-proofing of the roof

*The roof is 6 ins. thick in one bay, 10 ins. thick in the next. The mezzanine floor is absent on one side of the column.

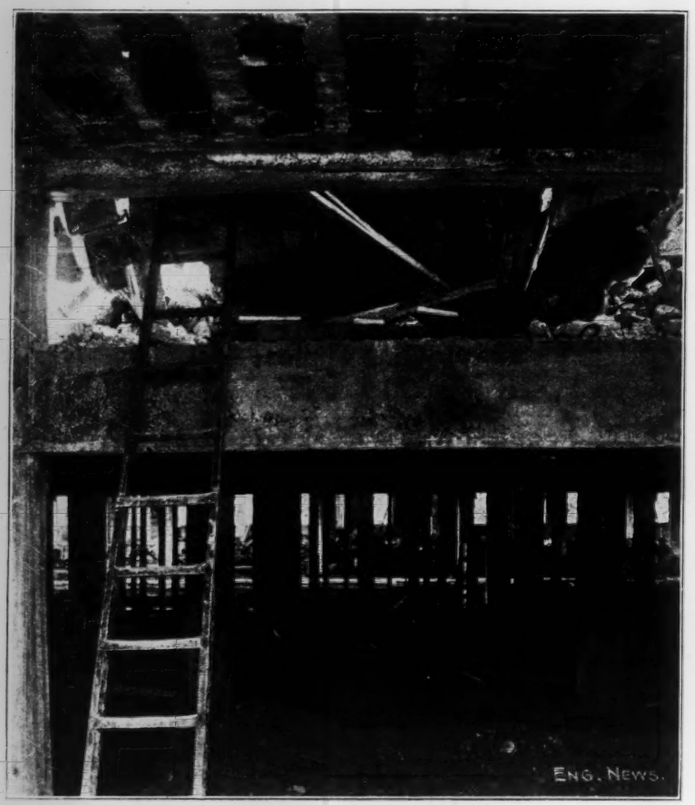


FIG. 8. A VIEW OF TWO FLOOR GIRDERS IN THE UNDAMAGED PORTION OF THE BUILDING.

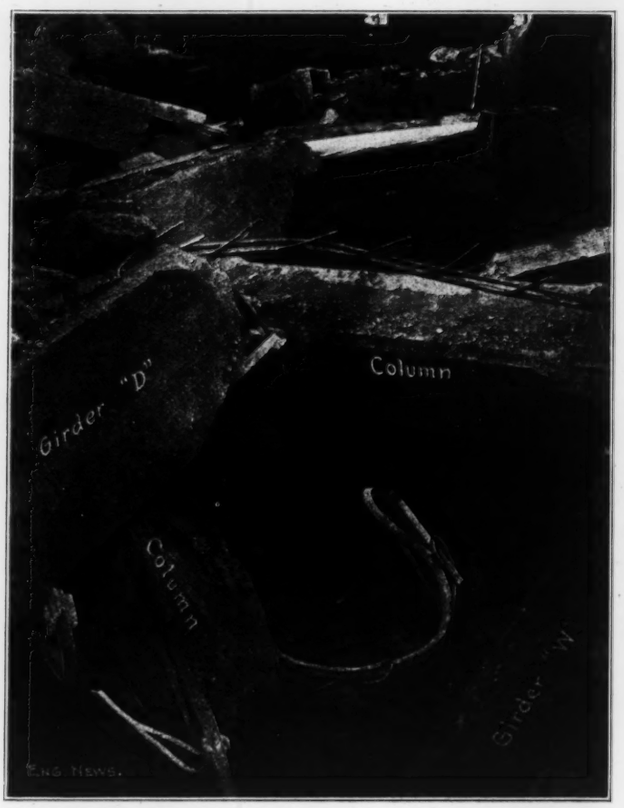


FIG. 11. COLUMN 47, WHOSE FAILURE PROBABLY INITIATED THE COLLAPSE; VIEWED LOOKING SOUTH.

was being put on, but had not reached the corner which fell, and workmen were removing the wooden supports under the portion that collapsed.

I find that the building collapsed because of the crushing of the lower portion of the steel-concrete column which is the sixth from the south side in the third row from the east side and marked No. 47 on the detailed construction plans. And column 47 crushed because it was improperly designed for the material of which it was composed and for the duty assigned to it, and the concrete was not properly compacted by tamping and its concrete was weakened by the presence of chips, leaves, sawdust and blocks of wood.

Fig. 10. Column 37 and Mezzanine Floor Girder.

Note knife stuck in joint of sawdust and shavings where column rests on mezzanine floor; knife stuck in large block of wood in column just above mezzanine floor level; and hole in corner of column below girder where the concrete was dug away by use of a wooden stick.

I find the Concrete Steel & Tile Construction Co., of Detroit, guilty of criminal negligence in submitting the working drawings, not in conformity with the agreement with the Eastman Kodak Co. and allowing pressures upon these columns beyond any safe limit.

I find William Costello guilty of criminal negligence, because, while in charge of the construction for the Concrete, Steel & Tile Construction Co., he allowed the cement to be put in the forms without proper tamping, so that holes were left in it, and allowed four steel rods to be put in a column where the plans called for six rods, and allowed four rods to be put in column 47 when the plans called for eight rods; and by gross and culpable negligence permitted leaves, sawdust, chips and blocks of wood to be put in the columns, thereby endangering the safety of the building.

I find Perley S. Wilcox, assistant manager of the Kodak Park works of the Eastman Kodak Co., who is an educated engineer and experienced in the construction of buildings, to be guilty of gross and culpable negligence; for the reason that, while the evidence shows he had and exercised control over the work of this construction on behalf of the Eastman Kodak Co., and had power to change the working plans and have removed defective construction and have careless workmen discharged, and even to stop the work; he, by gross and culpable negligence, allowed the contract to be violated so as to endanger life, by permitting column 47 to be constructed far weaker than was called for by the original plans made under his direction, and weaker than allowed by the building ordinances of the city of Rochester, although the contract specified that the plans should conform to such ordinances; and he was guilty of gross and culpable negligence when, recognizing his responsibility of inspection of the work in progress, he allowed to be employed a teamster, utterly devoid of experience in building, as sole inspector, without instructions as to the importance of the work he was inspecting, so that the moral effect of such inspection was bad, except, possibly, for impelling haste in the work rather than care for its integrity. He was guilty of gross and culpable negligence in not removing work which was obviously defective, like blocks of wood and joints of sawdust at the bases of columns, when the contract specified as follows:

The contractor agrees that the owner shall have power to cause any improper, inferior or unsafe work to be taken down and altered, and that all improper, inferior and unsafe work will be taken down and altered at the cost of the contractor and without charge or expense to the owner * * * and if at any time the contractor shall refuse to remove any work or materials rejected by the owner, then, and in that case, the owner, or such other agent as the owner may designate, may, upon five days' notice, declare this contract forfeited * * * the same as if this contract had never been made.

He was guilty of gross and culpable negligence in permitting column No. 47 to be constructed so that it would be subjected to a stress considerably greater than is consistent with or is considered safe in any building ordinances or engineering practice that has been brought to my knowledge.

CONCLUSIONS OF FACT.

I also draw the following conclusions of fact from the evidence and the study of this accident:

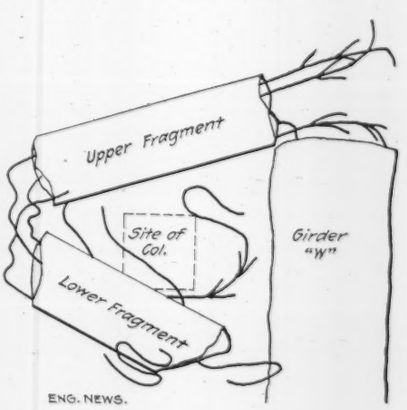


Fig. 13. Sketch Plan of Location of Column 47 in the Ruins (Girder D not Sketched).

First—The "Kahn" bars, and similar bars, with shear members attached, are not suitable for columns, because of difficulty in properly tamping the concrete.

Second—No steel-concrete structure can be considered safe unless some reliable man is absolutely responsible for putting the proper number of proper sized bars in the positions designated for them.

Third—The allowable stress upon steel and concrete in construction should be fixed by law, so that the safety

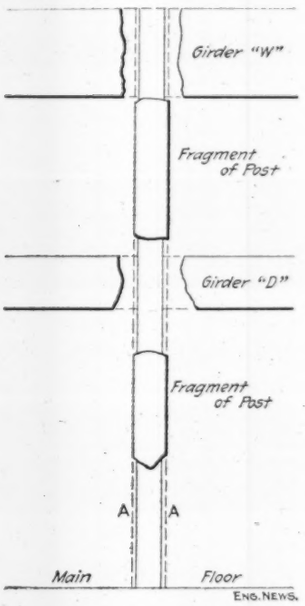


Fig. 14. Restoration of Column 47 and Attached Girders, Showing Portions Found in the Ruins.

The lower portion A was found with the outside flaked off in pieces from 6 to 10 ins. long by 3 to 4 ins. wide and showing the marks of the rods, while the balance was broken up fine and the rods bent up into double loops.

of the public will not depend upon the cupidity of energetic contractors or parsimonious designers.

I recommend to the Monroe county delegation in the Legislature that:

Chapter 415 of the laws of 1897, known as the "Labor law," which provides for the protection of labor in the building and operation of factories in cities, should be enlarged so as to provide for the approval of plans and supervision of construction of factories which are located outside of cities, as it is well known that one of the strong reasons for building factories in the country is to escape the interference of public officials and avoid the additional expense of construction which a compliance with public building ordinances implies.

December 20, 1906. Thomas A. Killip, Coroner.

The contract for the construction of the building made no specifications as to stress, but provided that

the said work is to be completed in strict conformity to all building laws, ordinances and regulations of the City of Rochester and State of New York.

The Rochester building ordinances contain the following clause, which is of special importance in view of the above agreement:

The safe bearing load to apply to concrete when Portland cement is used shall be taken at 15 tons per superficial foot.

The load is equivalent to about 208 lbs. per sq. in. The ordinances also define "reinforced concrete" and "armored concrete," and prohibit concrete columns above the first floor.

WORK ON THE 1,000-TON BARGE CANAL AND ON IMPROVED HIGHWAYS IN NEW YORK.*

In the construction of the 950 miles of canals in New York State prior to the Barge canal, the plan of building artificial channels was generally adopted, by far the greater part of their length being by independent canals, the natural waterways being utilized only to a small extent.

A study of the history of canal-building in this country shows us that the first attempts at improvement were in the beds of the natural streams, but the failures of the early projectors to cope with the difficulties of rapid current, flood and drought taught them to adopt the European method of building on the hillsides along the valleys of the streams, which were utilized only as a source of water-supply. The commissioners appointed by the New York Legislature in 1810 to investigate the subject of canals say in their report, "that experience has long since exploded in Europe the idea of using the beds of rivers for internal navigation."

In New York State, the experiment with natural streams was made by a private company—the Western Inland Lock Navigation Co.—and when canals were begun by the State, their course was along independent channels. In building the original Erie a side-hill location was very generally selected, probably for ease and cheapness of construction, and invariably a towing-path was constructed upon one bank.

In the early canals of comparatively small dimensions, before railroad competition grew so strong, these artificial channels, with their propulsion by animal power, could be successfully operated. The conditions now, however, are entirely changed; large channels are necessary, and these can be placed to best advantage in the lowest parts of valleys. The need of providing suitable competition with railroad freight rates led European countries to undertake the reconstruction and modernizing of their waterways about 25 years ago, but America is still in the first stages of this work.

The new Barge canal utilizes natural waterways wherever possible and is essentially a stream and lake canalization scheme. Of the 440 miles of canal, from 350 to 380 miles follow the course of some lake, river or other natural waterway. For only about one-quarter of the total distance are any portions of the existing Erie or Oswego canals utilized.

DIMENSIONS OF PRISM AND SIZE OF LOCKS.

The minimum depth of water will be 12 ft., the minimum width on the bottom in canal sections will be 75 ft. and in river sections 150 ft.

The Barge Canal Improvement Law of 1903 required that all locks should have a clear width of 28 ft., with a minimum depth of 11 ft. of water over the miter-sills. Under this law plans had been prepared and two contracts let for locks of 28 ft. width and 12 ft. depth. This law, however, was amended in 1905 by an act which permitted these dimensions to be increased, but did not definitely fix the size. After very careful investigation and consideration, the width decided upon was 45 ft. and the depth 12 ft., despite the recommendation of the State Engineer and the Advisory Board of Consulting Engineers that a depth of 14 ft. be adopted.

Before reaching this decision a very thorough study was made of the widths of locks on canals of a similar character, previously built in the United States and Europe. Careful consideration was given to the fact that the width of the canalized, natural waterways was sufficient for boats 43 ft. wide to pass each other, throughout about 92% of the distance between New York City and Rouses Point, at the northern end of Lake Champlain, and about 85% of the distance between New York City and Oswego, on Lake Ontario, or about 76% of the total length of the proposed Barge canal—including the Erie, Champlain and Oswego branches, and covering the distance from New York City to Rouses Point, Oswego and Buffalo. The fact that the locks on the Canadian system of canals were 45 ft. in width and had 14 ft. depth of water on the miter-sills was also considered, especially since the New York canals are connected with the Canadian system by Lakes Erie, Ontario and Champlain, with a possibility that Lake Champlain may be connected with the St. Lawrence River at Montreal at some future time by a Canadian canal, which would probably have the same dimensions of lock. Consideration was also given to the great increase in the carrying capacity of barges having a width of 43 ft. over those of only 27 ft. in width.

*Extracts from the Report of Henry A. Van Alstyne, State Engineer, covering the work of his department for 1905 and 1906.

MOVABLE DAMS.

Many difficulties were experienced by the earlier canal builders from the use of fixed dams in streams with a widely fluctuating flow, and, therefore, in the canalization of these streams for the Barge canal, it has been decided to adopt the comparatively modern device of movable dams, wherever their advantages make this course seem desirable.

The use of movable dams has been quite general in Europe for many years and more recently they have been employed on some of the rivers canalized by the United States Corps of Engineers for the United States Government, especially on the Ohio and Monongahela and other rivers of the South and Middle West. Many of the movable dams built in Europe and the United States have been examined by engineers of this department during the last year.

The report of Mr. D. A. Watt, Expert Designer of Movable Dams, giving the result of his investigations and observations, during the summer of 1905, on the European practice, is printed as an appendix to the report. The advice of Major William L. Sibert, U. S. Corps of Engineers, of Pittsburg, Pa., has been obtained with reference to the general plan for canalizing the Mohawk River. After this thorough consideration of the subject, finally with the approval of the Advisory Board of Consulting Engineers, it has been decided to adopt the bridge type of dam for use on the lower Mohawk River.

The bridge type of dam has been used with success on the Moldau River in Bohemia, and it is planned to adopt this type of dam on portions of the River Seine in France. The use of this dam permits the control of water-surfaces to a much greater degree than would be possible with any fixed dam, and, except during floods, these water-surfaces can be maintained at a higher level than would be possible by using a dam with a fixed crest, for the reason that in the time of flood the movable portion of the dam may be removed to a sufficient degree to prevent damages that would necessarily result from the use of a fixed dam of the same height of crest. The use of the movable dam also permits the river to be restored to its natural condition during the season when the canal is not in use.

Moreover, in time of flood the silt, debris and detritus is washed down-stream instead of accumulating in the pool above the dam. Not only will these movable dams together with the adjacent sections of canal be cheaper in construction, reduce the cost of the completed canal in lessened excavation and flood damages, but it is believed that by their use a large amount of money will be saved also in the subsequent maintenance of the completed canal, both in the amount saved in dredging and in the lessened amount of flood-damages which would be caused with other types of fixed dams.

ORGANIZATION OF ENGINEERING FORCE.

All surveying, designing and supervising of construction is done by the barge canal department of the State Engineer's office. The entire force of engineers, draftsmen, clerical employees and laborers varies from 200 to 400 men at different seasons of the year. Every employee in the department is selected in accordance with the State civil service laws. The organization of the engineering force is as follows:

State Engineer and Surveyor.....Henry A. Van Alstyne
Special Deputy State Engineer.....Henry C. Allen
Special Resident Engineer (Principal Assistant to the Special Deputy).....Wm. B. Landreth
Division Engineer.....In charge of division
Resident Engineer.....In charge of residency
Assistant Engineer.....In charge of contract
Levelers, Draftsmen, Rodmen, Chainmen and Laborers.

The territory of the State is divided into three divisions. The work on the various divisions is under the supervision of the division engineer of that division. Each division, and the separate canals on each division, are divided into residencies. The work on each residency is under a resident engineer. On each residency there is a sufficient number of assistant engineers, levelers, draftsmen, rodmen, chainmen and laborers employed to carry on the work on the residency.

After the survey maps have been made at the various residencies, the residency force prepares general maps for the contract plans and certain portions of the contract drawings. The information relating to structures

FIG. 12. A SECTION OF CONCRETE FLOORBEAM, SHOWING THE SURFACE WHICH WAS IN CONTACT WITH TILE.

is transmitted to the office of the Special Deputy State Engineer and the plans for structures and special portions of the general plans for contracts are prepared in that office.

The work in the office of the special deputy is divided into various bureaus—known as the bridge, general drafting, river, lock, computing and checking bureaus. Each bureau is in charge of an expert, and under his supervision the plans, estimates and specifications are prepared for the structures on the proposed work.

When the plans for any contract are completed and approved by the Special Deputy State Engineer, they are sent to the State Engineer for his approval, then to the Advisory Board of Consulting Engineers for action and then to the Canal Board for the final approval. After the plans, specifications and estimates are approved by the Canal Board, the Superintendent of Public Works calls for bids from contractors for doing the work. If satisfactory bids are obtained, a contract is made by the Superintendent of Public Works with the lowest bidder, who proceeds to construct the work under the terms of the contract.

By the provisions of the Barge Canal law, the actual work of construction is under the direction of the State Engineer, subject to the final acceptance and approval of the State Engineer and the Superintendent of Public Works. The work of construction on any one contract is carried on under the supervision of the division, resident and assistant engineer in charge, with such other assistants as the work requires.

For the first time in the history of New York State canal work, the Barge canal contracts provide only one lump sum for each cubic yard of material excavated of every name and nature, no attempt being made to classify the different materials excavated as earth, rock, hardpan, etc. The results have been very satisfactory in every way. Contracts were awarded at prices as low as probably would have been obtained under the old method of different prices for earth and rock excavation, and in the actual execution of the contract there has been no occasion for the frequent disputes and differences of opinion so common under the old method, as to just what material should be classified as earth or as rock.

To enable the contractors before bidding to ascertain the quantities of different classes of material which the plans required excavated, it was thought advisable to make an exhibit to the contractors of a very complete set of borings over the area of each contract. For this purpose a large number of wash drills were constructed, crews organized for their operation, each under a competent foreman with two or more assistants. Samples of the borings were taken at regular intervals and preserved in glass bottles properly labeled. These wash drills were used for drilling through the earth until rock was reached.

On all structures where rock excavation was required, the character and nature of the rock was determined by borings made in the rock by shot drills and the cores of the rock were carefully preserved and exhibited to all bidders for each contract. About 214,000 lin. ft. of borings in earth have been made and about 2,800 lin. ft. of rock borings have also been made. The records of the drilling parties were kept in regular daily report sheets, filed in the resident engineers' offices.

Contracts have been let for about $20,000,000 worth of work distributed as follows:

On the Erie canal from Waterford on the Hudson River to Crescent; for dams between Schenectady and Little Falls; for six miles of canal at the east end of Oneida lake; for 5.7 miles of canal in the Seneca River east of Savannah; for 3.3 miles of canal in deep rock cut at the western limits of the city of Rochester; and for 12.5 miles between Pendleton on Tonawanda Creek and Tonawanda on the Niagara River. On the Champlain canal from Northumberland to Whitehall, a distance of 33.7 miles, and for dams and locks on the Oswego canal at Fulton.

As above described the surveys for the whole 440 miles of barge canal have been nearly completed. Plans have been completed, approved by the advisory board and canal board and placed under contract for about twenty million dollars' worth of work and the contractors are making satisfactory progress on same. This work includes five locks at Waterford intended to take the place of the 16 locks at Cohoes, overcoming the difference of elevation of 170 ft. between the Hudson River at Waterford and the upper Mohawk at Cohoes. Each of these locks will have a lift of about 34 ft., which is the highest of any locks of this type ever constructed in this country.

The total length of the work under contract is about seventy miles.

The estimated cost of the work actually under contract is about two million dollars less than the estimated cost for the same portions of the canal, made at the time the $101,000,000 act was prepared, for which provision was made in that law. This work has been placed under contract, too, when the prices of labor and material were very much higher than when the $101,000,000 estimate was prepared. The work also includes 21 locks which have been widened to 45 ft. in width instead of the 28 ft. wide lock, provided for in the original estimates.

In addition to the twenty million dollars' worth of work under contract, plans for about eighteen million dollars' worth of work have been completed and are ready for submission to the advisory board and the canal board and plans for about twelve million dollars' worth of work are far enough advanced to permit their completion within the next three months. To summarize, plans have been prepared by this department for about thirty-eight million dollars' worth of work, providing for a total length of about 200 miles of canal.

HIGHWAY IMPROVEMENT WORK.

The 75,000 miles of wagon roads of New York State were for the most part originally located, constructed and have heretofore been maintained without any intelligent or systematic plan which would enable the people paying for and using them to obtain the best possible results for the amount of money expended. For the first time in its history, the State of New York is now, however, fairly started upon a systematic and carefully considered plan for the construction, maintenance and repair of her roads. Nearly $7,500,000 have been expended during the past seven years in the improvement of these main highways and nearly $50,000,000 more are available for this purpose, should the legislature see fit to authorize bonds to be sold.

If the next legislature approves the state highway map designating the main market roads which are to be improved by State aid under the $50,000,000 bond issue, we may feel assured that within the next ten years her main highways will be improved. Surveys and plans for the improvement of about 2,500 miles of these main roads have been approved by the various boards of supervisors throughout the state. Of these 2,500 miles about 800 miles have been constructed, and in addition thereto, between 500 and 600 miles are under contract and will be completed during the coming year.

Improved roads have been petitioned for in every county of the state outside of Greater New York, except three. If the present plans are carried forward, it is probable that the main highways of each county will have been improved within a decade, and these when joined to those of adjacent counties will constitute a State system which will place every farm in the State within a few miles of some main road in this system.

In the improvement of these main roads wherever it is of advantage to do so, the faulty locations over hills or into deep valleys with steep grades have been improved as far as possible and the drainage has been made as nearly perfect as conditions will permit. This has involved on most roads the replacing of nearly every wooden culvert with a substantial masonry structure, and a macadam or gravel surface has been provided.

For the maintenance of these main highways a law has been enacted which places their care under the charge of the State Engineer. It is to be hoped that after this year the legislature will make sufficient appropriations to permit all of these main roads to be maintained in suitable condition so that the expense of this work to the towns will not exceed $50 per mile.

ROADS MAINTAINED UNDER THE MONEY SYSTEM.—For all roads (comprising over 65,000 miles) other than the main highways to be permanently improved as above described, the Money System of maintenance is recommended and has been voluntarily adopted by over two-thirds of the towns of the State. In these towns the State pays one-third of the cost of maintenance, and during the years 1905 and 1906 has contributed over one million dollars for that purpose.

I would recommend that those towns which have not adopted the Money System by a vote of their citizens, be placed under this system by act of the legislature in order that a uniform practice may prevail over the entire State.

I would also recommend that only one highway commissioner be permitted in each town, as it has been my experience that the best results are secured by having one responsible head to care for the roads in each town, rather than to have a division of authority as now exists in 114 towns.

Like everything else belonging to the public, private interests have, in many cases, encroached upon the rights of the public in the highways of the State. I would strongly recommend that no electric railway, telegraph, telephone or water company or other corporation or individual, be permitted to use, occupy or in any way encroach upon the rights of the public to the highways of the State unless it is under a revocable permit issued by the town and state authorities and containing such conditions and restrictions as these authorities may see fit to impose in order to protect the rights of the public in their own property, and that the necessary legislation be enacted to enable the authorities to enforce the conditions of such permits and to punish violations of the law in regard to encroachments.

In many cases roads that have been constructed with great care and expense by the State, have been seriously damaged and injured by the use of heavy loads on narrow ties and also by individuals carrying or dragging enormous weights, such as boilers, logs and other heavy materials over the roads in such a way as to injure them, and also by the users of adjacent property filling up ditches or culverts and interfering with the drainage of the road. I would recommend that such legislation be enacted as will permit the State and town authorities to protect these roads from wanton damage and injury.

I desire again to call attention to the fact that, under section 145 of the Highway Law, no town or its officers can be compelled to accept or pay for any iron or steel bridge exceeding 200 ft. in length, or having a span or spans exceeding 100 ft. in length, until the State Engineer and Surveyor shall certify to the completion of the bridge, pursuant to the contract under which it shall have been constructed.

The provisions of this law are usually evaded in practice, and it affords very little protection to the taxpayers of the various towns. I recommend that this law be amended in such a way as to require the approval of the county engineer, where there is one, and the State Engineer, of the plans and specifications of every bridge contracted for by the town that exceeds $500 in cost. Also, that after the approval of such plans, the contract for every bridge be awarded to the lowest responsible bidder, based upon the approved plans therefor, after the same has been properly advertised in two papers published in the county in which the bridge is located, and also in some paper devoted to engineering and contract work published within the State.

STATE AND COUNTY BOUNDARY LINES.

The completion of the re-survey and the re-monumenting of the New York and Canada boundary lines in 1902 and 1903 and of the New York-Vermont line in 1904 has left all our State boundary lines, with the exception of New York-Connecticut, properly and plainly marked with substantial granite monuments. We are in hopes during the coming year to secure the co-operation of the State of Connecticut for a re-survey of the New York-Connecticut line. The many disputes which have arisen in the Adirondacks, due to the fact that while these county lines were established by statute more than one hundred years ago they were never actually marked on the ground, has been removed by the surveying and the marking on the ground of these different lines.

EXAMINATION QUESTIONS, CHIEF OF THE BUREAU OF WATER, PHILADELPHIA.

The various public works of Philadelphia are administered by a Director of Public Works, under whom are chiefs of bureaus. On Dec. 4, 1906, a written and oral examination was held to secure an available list of candidates for the position of Chief of the Bureau of Water. The position yields a salary of $6,000 a year. The questions were prepared, the examination was conducted and the answers were (Dec. 21) being marked by an examining board, acting under the direction and with the cooperation of the Civil Service Commission of Philadelphia. The members of the examining board were: John C. Trautwine, Jr., M. Am. Soc. C. E., formerly Chief of the Bureau of Water; Major Cassius E. Gillette, Chief Engineer of the Bureau of Filtration, formerly of the Engineering Corps of the United States Army; and Wilfred Lewis, M. Am. Soc. M. E., president of the Tabor Manufacturing Co.; all of Philadelphia.

We are indebted to Mr. Cyrus D. Fox, Jr., Secretary of the Commission, and to Mr. Trautwine for a copy of the questions, which we reprint below. In our issue of May 16, 1895, we reprinted a previous set of questions used in examining candidates for this same position.

In the present examination the weight of each question, in the written examination, was stated on the list before the candidate, as shown below. On a basis of a total of 1,000 the written examination was weighted at 600, divided as follows: Civil engineering, 170; mechanical engineering, 200; administrative and general, 200; manner of preparation of paper, 30. On the oral examination (questions not sent us) civil and mechanical engineering were given a weight of 100 each, and administrative and general was given 200, making a total of 400. The written questions follow:

EXAMINATION QUESTIONS, CHIEF OF THE BUREAU OF WATER, PHILADELPHIA.

CIVIL ENGINEERING.

(1) What is the chemical composition of pure water? Value 3

(2) What is its weight per cubic foot? Value 4

What is meant by "hardness" in water? How is hardness caused? What are its effects

ion steam boilers, cooking, toilet-use? How ay hardness best be obviated or removed? Value 4

(4) A reservoir bank has a slope of 30° to the orizontal. The water is 30 ft. deep. What is e total normal pressure in pounds upon a suberged strip of the bank, 1 ft. wide, reaching om top to bottom, and where is the center of ressure? Value 10

(5) How is the resistance to flow in water pipes ffected by (a) pressure, (b) velocity, (c) cross ction area, (d) length, (e) kind and condition f pipe? Value 8

(6) Give the Chezy formula for the velocity of ater in pipes and in channels, and define the ctors employed in it. Value 5

(7) Sketch a profile of a pipe line, 3 miles long, diameters diminishing from 4 ft. to 1 ft., fed om a reservoir with 100 ft. total head and disharging freely at its lower end and not elsehere, showing by an *approximate* location of he hydraulic grade line how the pressures might e expected to vary in the several parts of the ipe. Value 8

(8) Explain the phenomena attending change of velocity of flowing water in pipes, as by closing a gate or starting a pump. Value 10

(9) Describe and explain (a) the Venturi meter, (b) the Pitot tube, as applied to flow in water pipes, and outline the principles of their action. Value 10

(10) State approximate lifetimes of reservoirs, pipe lines (of cast iron and of riveted steel), boilers, pumps, buildings. Value 10

(11) For what purposes and under what conditions would you use a centrifugal pump? Value 5

(12) What results have been obtained by multistage centrifugal pumps? Value 5

(13) Name the principal methods of water purification, other than filtration. Value 4

(14) What is accomplished by (a) sedimentation, (b) hasty filtration, before final filtration? Value 4

(15) What are the principal differences between slow and rapid filtration? Describe each. Value 10

(16) How is the rate of filtration usually regulated (a) in slow filters, (b) in rapid filters? Value 4

(17) What bacterial efficiency may reasonably be expected of (a) slow filters, (b) rapid filters, and at what maximum rates of filtration may these efficiencies be ordinarily obtained? Value 4

(18) For a filter plant furnishing 40,000,000 gals. daily to a residence district, and always amply supplied with raw water, what storage capacity should be provided for filtered water? Value 8

(19) In what forms is asphalt applied, in the lining of reservoirs, and how does its use affect the behavior of the reservoir? Value 4

(20) What considerations determine the thickness of water pipe? Value 8

(21) Describe the operation of laying cast iron pipe, including the opening of the ground, refilling and repaving. Value 8

(22) Describe (a) a joint in cast iron pipe, (b) a 56-in. gate valve, (c) a 36-in. check valve, (d) a fire hydrant. Value 10

(23) What are primary requisites in the making of concrete (a) for foundations, (b) for watertight structures? Value 10

(24) Describe some of the best known "systems" of reinforcement. Value 4

(25) A covered filter plant, of reinforced concrete construction throughout, is to have a 12-in. flat floor, columns 12 ins. square and 15 ft. c. to c. and flat roof 12 ins. deep. Sketch a vertical section through two columns, of a portion of this filter, showing your arrangement of the reinforcement. Value 10

MECHANICAL ENGINEERING.

(1) What relation does the safe working stress of cast iron bear to its ultimate breaking strength, and what is this relation generally called? Value 6

(2) What do you understand by the term elastic limit? Value 4

(3) What do you consider a safe working stress per square inch in cast iron pipe? Value 4

(4) State the relation between the weight of a concentrated center load upon a horizontal rectangular beam, and the maximum fiber stress caused by such load. Value 10

(5) How does this maximum fiber stress under the breaking load compare with the maximum tensile stress as shown by direct tension in a cast iron beam, and how do you account for the difference? Value 6

(6) What coefficient of friction would you expect in a well-lubricated journal when just starting or moving very slowly, and what in the same journal running at the rate of 200 or 300 ft. per min.? Value 6

(7) About what percentage of the heat developed in burning coal can be utilized in the generation of steam? Value 10

(8) What percentage of the heat converted into steam can be reconverted into mechanical energy in the best modern steam engines? Value 10

(9) What is the meaning of Joule's equivalent? Value 6

(10) Describe some of the types of boilers in common use and state their chief merits and defects. Value 10

(11) How is the horse-power of a boiler determined? Value 10

(12) In a water tube boiler, about what relation should exist between heating surface and grate surface under natural draft, and what evaporation would you expect per square foot of grate surface? What gain in capacity is to be expected from forced draft? Value 10

(13) In condensing steam engines, what is ordinarily the ratio between (1) the work done in emptying the condenser and (2) the economy due to condensation? Value 4

(14) Describe and explain the barometric condenser. Value 4

(15) In the transmission of power, upon what does efficiency depend, and how does the loss in effect reappear? Value 6

(16) In what do the losses in belt transmission consist? Value 4

(17) Enumerate some of the means employed in the transmission of power and say what medium you would prefer in the operation of a portable drill, chipping hammer, wheel press, traveling crane, turning lathe. Value 8

(18) What is meant by the duty of a pump? Value 10

(19) In what terms is duty usually expressed? Value 6

(20) How is the duty ascertained? Value 6

(21) By what means, chiefly, is high duty secured? Value 10

(22) How is duty affected by steam pressure, by water pressure, and by capacity? Value 6

(23) What duties are to be expected from (a) triple-expansion crank-and-fly-wheel pumps, (b) compound crank-and-fly-wheel pumps, (c) compound direct-acting pumps, of 20,000,000 gals. daily capacity, 200-ft. lift, boiler pressure 150 lbs. per sq. in.? Value 10

(24) Describe and explain the effect, upon a pumping engine, of air, taken into it through the suction main, and state how this difficulty may be obviated. Value 4

(25) Describe the manufacture of cast iron pipe. Name some of the more usual defects to which such pipe is subjected. Value 10

(26) What is the effect, in iron and steel manufacture, of (a) carbon, (b) sulphur, (c) phosphorus, (d) silicon, (e) manganese, (f) nickel? Value 10

(27) What are the chemical and structural differences between (a) cast iron, (b) wrought iron, (c) structural steel, (d) tool steel? Value 10

ADMINISTRATIVE AND GENERAL.

(1) What has been your experience in waterworks construction and management? Value 20

(2) What experience have you had in administrative or technical positions in general? Value 20

(3) What educational advantages did you enjoy before entering your active life? Value 15

(4) What experience in practical mechanics have you had? Value 5

(5) What field experience in civil engineering have you had? Value 5

(6) What is the procedure followed in taking land by eminent domain? Value 5

(7) What should be the practice, in a municipal supply, as to ownership, control, maintenance and repair of service pipes, meters, attachments? Value 5

(8) What regulations should govern (a) advertisement for bids, (b) awards of contracts, (c) provision of money to cover cost? Value 5

(9) In a pumping station containing four triple expansion vertical pumps, each lifting 20,000,000 gals. daily to a height of 200 ft., fed by 24 tubular, return-flue boilers; with hand feeding, and running three turns of eight hours each, what men should be employed on each shift, what would be their several duties and responsibilities and what wages should be paid them in order to secure the highest economy and efficiency? Value 20

(10) In a residence distribution district, having a population of 200,000, on an area of four square miles, with a range of elevation of 50 ft., with 40 miles of streets 50 ft. wide between house lines, and with single trolley lines on 50% of the streets, what men should be employed on each shift, what would be their several duties and responsibilities, and what wages should be paid them in order to secure the highest economy and efficiency? Value 10

(11) What are the principal sources of waste in a municipal water supply? Value 5

(12) To what extent does waste affect the efficiency of a water supply, and its cost of construction and operation? Value 5

(13) Describe methods of waste restriction, their advantages and disadvantages. Value 5

(14) What is a proper per capita allowance in cities, including unavoidable and reasonable waste? Value 5

(15) How can these methods be prevented from causing restriction of *use* of water? Value 5

(16) What have been found to be the principal objections to the use of water meters as applied to domestic services? Value 5

(17) Write a letter to a contractor who has failed to comply with the terms of a specification, describing the nature and extent of his failure and stating what you require of him in the premises. Value 10

(18) What experience have you had in the management of men? Value 10

(19) What emergencies have you met and how have you surmounted them? Value 10

(20) How would you arrange to keep yourself advised as to the costs of the several branches of the work of a city water bureau? Value 10

(21) What is the final test of merit in the carrying out of engineering and administrative purposes? Value 10

(22) Give some prominent engineering work with which you are familiar and criticise the merits and defects of its plan and construction. Value 10

(23) What is your idea for obtaining the largest return from labor for a given expenditure in wages? Value 10

A DOUBLE-DECK SWING BRIDGE has been built across the River Avon at Bristol, England, to connect the Great Western Ry. with the system of railways around the harbor and docks and with a new freight yard and station. The swing span is 202 ft. long, with unequal arms, and weighs about 1,000 tons; there is a short fixed span at one end, and the roadway is carried over the railway approaches by viaducts, making a total length of about 600 ft., exclusive of the incline approaches. A double track railway crosses the lower deck, while the upper deck has a 20-ft. roadway and two sidewalks 5 ft. 6 ins. wide. The rail lifts are locked with the railway signals and also with signals placed up and down the river to warn vessels of the position of the bridge. When the bridge is to be opened, the end locks are released independently by the signalman at block stations near the bridge, and they cannot do this unless the railway signals have first been set to indicate "stop." The release of the locks also releases the levers for operating the bridge, so that the bridge tender cannot swing the bridge until the signalmen have set their signals and released the locks. The bridge was designed under the direction of Mr. W. W. Squire, M. Inst. C. E., Harbor Engineer. The steel structure was built by the John Lysaght Co., of Bristol, the hydraulic machinery by Sir Wm. Armstrong, Whitworth & Co., and the signal and interlocking plant by Saxby & Farmer.

THE EMPIRE RESERVOIR OF THE BIJOU IRRIGATION DISTRICT, COLORADO, AND ITS EIGHT DAMS.

A 1,643,000,000-cu.-ft. reservoir, formed by eight dams, having an aggregate length of 25,534 ft., or nearly five miles, is under construction about 18 miles west of Fort Morgan, Colo. The Empire Reservoir, as it is called, is being built

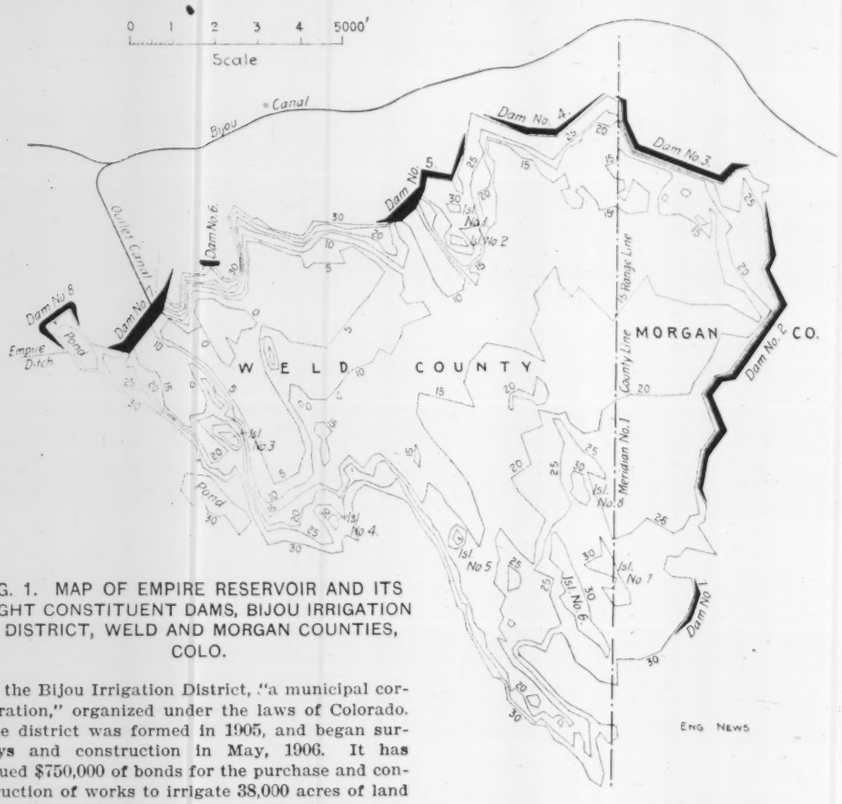


FIG. 1. MAP OF EMPIRE RESERVOIR AND ITS EIGHT CONSTITUENT DAMS, BIJOU IRRIGATION DISTRICT, WELD AND MORGAN COUNTIES, COLO.

by the Bijou Irrigation District, "a municipal corporation," organized under the laws of Colorado. The district was formed in 1905, and began surveys and construction in May, 1906. It has issued $750,000 of bonds for the purchase and construction of works to irrigate 38,000 acres of land in Morgan Co., Colo. Mr. W. B. Chapman is president and Mr. Galway Layton is secretary of the district, the offices of which are at Fort Morgan, Colo. The engineer for the work is Mr. C. D. Page, and the contractor, Mr. D. A. Camfield, both of Greeley, Colo.

A map of the reservoir and dams is shown by Fig. 1 and a typical cross-section of the dams at maximum height by Fig. 2. The character of the material forming these earth embankments being a sandy loam, they are given a very flat inner slope, as shown by Fig. 2. The reservoir being for storage only, and having practically no direct tributary drainage area, the dams have no spillways. The bottom of the outlet pipe of the reservoir is at Elev. 0, thus making 30 ft. depth of water available. At 10 ft. depth the water area will be 430.1 acres and the available storage capacity will be 101,000,000 cu. ft.; 20 ft. depth, 1,923.45 acres and 594,000,000 cu. ft.; 30 ft., or full depth, 2,841.69 acres (about 4½ sq. miles) and 1,643,000,000 cu. ft. capacity.

The reservoir will be filled from the South Platte River, through an inlet ditch (the Empire) about 21 miles long, having a bottom width of 30 ft., inner slopes of 2 to 1, a water depth of 6 ft. and an estimated carrying capacity of 600 cu. ft. per sec.; the grade being 1 ft. in 5,000 ft.

The estimated cost of the work is as follows: Diversion dam, head-gate, etc., $25,000; inlet canal, $180,000; dams, $205,000; outlet culverts, gates, etc., $20,000; total, $430,000, not including main outlet and distributing canals, etc.

On Nov. 30, 1906, four-fifths of the intake canal had been completed, as well as the outlet culvert and gates, and the dams were up high

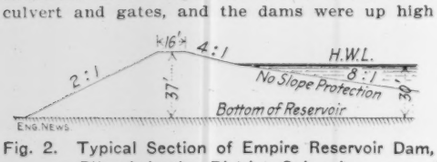


Fig. 2. Typical Section of Empire Reservoir Dam, Bijou Irrigation District, Colorado.

enough to allow the storage of 16 ft. of water, which it was thought would be available for irrigation in 1907. High water of the early autumn has delayed work on the dam and other head works at the river, but the river is now (Nov. 30) falling, work is renewed and it is believed these structures will be finished before the spring rise (1907). For the information given we are indebted to Mr. T. W. Jaycox, State Engineer of Colorado, Denver, Colo.

The following description of the sand chutes provided at the upper end of the canal, has been sent us by Mr. Page:

In early summer, at the season of high floods in the river, when the ditches are carrying a full head of water, great quantities of sand roll along the river bottom and entering the headgates of the ditches taking water from the South Platte are carried down the ditch until the decreased velocity of the current caused by the lighter grade of the ditch causes it to stop. It then forms obstructive bars in the ditch, which, as the river falls, sometimes entirely close the channel of the ditch.

To prevent the formation of these bars a sand chute of special design (Fig. 3) has been placed 6,600 ft. below the head, where the ditch approaches to within 200 ft. of the river, with a channel opening into the river. At this point the ditch bottom grade is 5 ft. above the surface of low water in the river.

The floor of this sand chute at the gates, which are placed at the side of ditch next the river, is 4 ft. below ditch bottom grade. It extends under and across to the opposite side of the ditch and also from the gates in the opposite direction 48 ft. toward the river, the river end being 1 ft. lower than the opposite end.

On the portion of this flooor caried under the main ditch six sluice boxes are mounted, extending across the ditch. These boxes are opened at the top for one-fifth their length, the openings lapping onto each other, alternating and placed so as to form a line of openings across the entire ditch bottom. These sluiceways are 1.5 ft. by 2 ft. high. The gates of the sand chute at the lower end of the sluices are raised 1½ ft. Water is drawn from the sluices only.

The purpose of the short and alternating sluice openings is to cover the entire cross-section of the ditch and to prevent overloading any one of the sluice boxes with too much sand.

The ditch is made larger above the sand chute, so as to admit of taking in an excess of water at the head and turning the excess through these sluices. It is proposed keeping a large head of water running through the ditch above the sand chute all the time. When the ditch is not allowed to take water *all* the sand chute gates are opened. The velocity of the current above the sand chute will by reason of this be so greatly increased as to scour the ditch clean of all loose sand between the headgate and the sand chute.

A system of sluices of like construction is also placed above the headgate.

All of the above structures were designed by Mr. Page, the District Engineer.

IS IT WORTH WHILE TO STRIP THE SURFACE SOIL FROM RESERVOIR SITES? REPORT ON STRIPPING THE ASHOKAN RESERVOIR SITE; ADDITIONAL WATER SUPPLY, NEW YORK CITY.

A report on stripping the site of the 120,000,000,000-gal. Ashokan Reservoir, projected for the additional water supply of New York City, has been made by Messrs. Allen Hazen and Geo. W. Fuller, M.'s Am. Soc. C. E., of New York City. As the report is really a treatise on stripping reservoir sites we gladly devote a number of pages of our space to it, and regret that we cannot publish it in full. The report is dated Nov. 30, 1906, and is addressed to Mr. J. Waldo Smith, M. Am. Soc. C. E., Chief Engineer of the Board of Water Supply, New York City. In brief, the report gives an extended historical review of the history of reservoir stripping, discusses practical experience with stripping in relation to the bottom and the top waters of reservoir, the first as regards stagnation and the second as regards odors of growth and disintegration, after which general discussion the specific problem of the Ashokan Reservoir is briefly considered. The conclusions of the report are against stripping, both as a general proposition, and for the Ashokan Reservoir, and in favor of relying chiefly on aeration and filtration for the prevention of odors and tastes in the water delivered to consumers. We say "relying chiefly," because cleaning and grubbing the site, so as to free it from trees, bushes, grass and weeds, is recommended: also the removal of stumps, etc., around the shores to a contour line 20 ft. below high water, and also the removal of any softer material, in swampy areas, that might become detached and rise to the surface after the reservoir is filled.

The problem under consideration is stated at

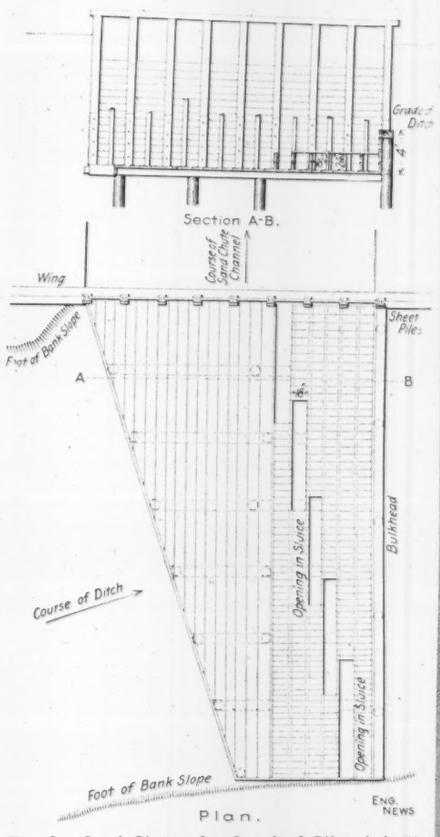


Fig. 3. Sand Chutes for Canal of Bijou Irrigation District, Colorado.

the opening of the report, after which the history of stripping is taken up, as follows:

RELATION OF RESERVOIR STRIPPING TO IMPROVEMENT IN QUALITY OF WATER.

In arriving at conclusions as to the effect of stripping reservoir sides and bottoms upon the quality of the water it is necessary at the outset to recognize that this subject relates particularly to bad tastes and odors, and also that there are several ways by which such tastes and odors may be eliminated.

It is also necessary to recognize that the proposed Ashokan Reservoir will cover an area of about 12 sq. miles and that over a large proportion of this area the water will have a depth of 50 ft. and over. As is well known, the temperature of the water in such large reservoirs varies much at different depths. For ten or eleven months each year the bottom water will have a temperature approaching more or less that of water at its maximum density, that is, about 39° F.; and as the lower depths are not reached by wind action they will remain stratified and separated from the upper layers. This stratification for six or seven months during the warmer portion of the year will be due, of course, to the action of the sun in causing the surface water to be warmer, and consequently lighter, than the bottom water. For several months in the winter the surface water will approach freezing temperature and then also will be lighter than the bottom water. Twice a year between these periods of stratification, once in the spring and once in the autumn, there will be a vertical circulation resulting in a thorough mixture of the water from the bottom to the top.

Bad tastes and odors in the water of such large storage reservoirs are produced in two general ways which are entirely different from each other and have no direct relation, as follows:

(1) BACTERIAL PUTREFACTION OF BOTTOM WATER.—This state of affairs results when the amount of organic matter in the stratified bottom layer of water, or in the soil of the bottom and sides of the reservoir, or in deposits or growths upon them, is so great that under the action of bacteria all of the oxygen in the water is used up in oxidizing the organic matter and converting it into simple compounds. When the bottom layers of water have their oxygen exhausted in this way the water is spoken of as "stagnant." Decomposition of the organic matter by certain kinds of bacteria continues in the absence of oxygen and produces certain changes spoken of as "putrefaction." These putrefactive changes are accompanied by bad tastes and odors due to various resulting compounds, the most conspicuous of which perhaps is sulphuretted hydrogen. These odors are spoken of as "odors of decay."

(2) DETERIORATION OF SURFACE WATER DUE TO ALGAE AND OTHER GROWTHS.—Usually those forms of microscopic animal and vegetable life, which are larger than the bacteria and which produce bad tastes and odors, live and multiply in the upper layers of reservoir water when sunlight is available. The effect of stripping a reservoir affects these growths almost solely by removing the food otherwise available from the sides and bottom. Algae and protozoa are the most conspicuous of the organisms which produce odors. The odors are produced either by the growing organisms themselves or are due to oily secretions liberated by the disintegration of the organisms. They are spoken of as "odors of growth and disintegration."

In addition to the question of odors the stripping of reservoirs is in most cases associated with quality of water from the standpoint of color or vegetable stain. The Esopus watershed above the proposed Ashokan Reservoir, with a drainage area of about 255 sq. miles, is usually free from swampy places, except for several tracts along Beaver Kill, which are practically within the flow line of the proposed reservoir. The water of the main stream of the Esopus is quite free from vegetable color, but as the color question plays such an important part in the history and present status of reservoir stripping we are obliged to touch upon it at some length in several places in this report in order to fully bring out the basis for certain ideas which prevail or have prevailed and which must be considered.

HISTORY OF RESERVOIR STRIPPING.

The stripping or removing of soil from the bottom and sides of reservoirs so as to eliminate at the outset practically all organic matter is a Massachusetts custom. For the most part the practice has been confined to that State.

In fact, so far as we can ascertain, there is scarcely an impounding reservoir outside of New England which has been thoroughly stripped.

In Europe, impounding reservoirs have not often been stripped; sometimes they have not even been grubbed. We have been able to learn of only three impounding reservoirs there which have been stripped. These are small and have been built on peaty areas. Stripping was undertaken apparently for the reason that at lower points on the same streams older reservoirs were found to have given trouble for a time in earlier years. One of these stripped reservoirs is near Bradford, England.

In India there are quite a number of large impounding reservoirs, but so far as we can ascertain none of them have been stripped. The same is true of several projects in Australia of which we have record.

In setting forth the practical results accomplished by stripping it is desirable to review briefly the record of the entire evidence and show what differences, if any, exist between conditions at the several points of observation and those likely to be met at the Ashokan Reservoir.

BOSTON ORIGIN OF STRIPPING.—About 25 years ago, particularly during the unusually dry seasons of 1881-82, seriously objectionable tastes were experienced in the water from some of the reservoirs supplying Boston. At that time the more recently constructed storage reservoirs of Boston had had the trees and brush growing on the bottom and sides cut down and removed or burnt. Shallow flowage had also been eliminated somewhat, but, generally speaking, there was no radical departure in Massachusetts from the practice elsewhere, although there was a well-defined tendency to make flooded areas cleaner.

Beginning about 1883 the cleaning of the bottom and sides of the reservoirs then under construction was undertaken systematically. Thus Reservoir No. 4 of the Boston water-works, now known as the Ashland Reservoir, built in 1882-85, was thoroughly cleaned of all loam, stumps and vegetable matter and was deepened wherever the original depth below high water was less than 8 ft. The Hopkinton Reservoir, built a little later, was similarly prepared, and the same has been true of all large reservoirs since built for the Boston supply. Two of the older reservoirs, namely, Framingham Reservoirs Nos. 2 and 3 of the Boston water-works, were also improved about this time by removing all stumps and much of the muck from the sides and bottom as far as they could be exposed by drawing down the water and by increasing the depths at points of shallow flowage. There were also a few comparatively small reservoirs elsewhere in Massachusetts which were prepared with clean bottoms and sides during this period.

DISCUSSIONS OF TASTES, ODORS, COLOR AND STRIPPING.—One-fourth of the report is devoted to a critical review of printed discussions of various phases of the subject.* This interesting and valuable digest we are compelled to pass over, in order that we may give more space to the authors' review of "practical experience" as to the relation between stripping and stagnant bottom water and tastes and odors in the top water of reservoirs.

RESERVOIR STRIPPING IN RELATION TO THE QUALITY OF WATER IN STRATIFIED BOTTOM LAYERS.

Precise analytical data on this subject being meager, it was necessary to have recourse to the general experience with large reservoirs, particularly those of Boston, New York, Newark, Jersey City, Liverpool and Birmingham. Most deep reservoirs have a stagnant bottom layer during a considerable portion of each year and the bottom water as drawn is more or less offensive and unsatisfactory.

Stripping reservoir sites, the evidence afforded chiefly by odors and colors in few cases indicates, merely delays stagnation until a deposit of organic matter has been formed.

BAD EFFECTS OF STAGNATION OF BOTTOM WATER.—These are summarized and commented on as follows:

(1) The amount of free carbonic acid in the water increases during the time when the oxygen is being exhausted through the action of bacteria upon the organic matter. This increase in free carbonic acid, facilitates the solvent action of the water upon lead pipes and in Great Britain seems to have had considerable practical significance with reference to lead poisoning.

(2) Odors of decay due to putrefaction of organic matters are found in the water as drawn from the bottom layers. These odors are largely due to compounds containing more or less sulphur and phosphorous. They result from the putrefaction of the organic matter originally present in the bottom and sides of the reservoir and in the water flowing into the reservoir, and also from that resulting from the organisms which either grow in the bottom layers or which reach there by settling down from the upper portions of the reservoir.

(3) The appearance of the water is made quite unsightly, due to the marked increase in the amount of organic matter dissolved by the water and to the iron which is extracted from the soil and which in a ferrous condition unites with the organic matter. The color and appearance of such stagnant waters is very high and unsatisfactory, particularly after partial aeration by exposure to the air.

(4) In the bottom layers many kinds of organisms are found; but so far as we can ascertain it is chiefly the fungi which grow in large numbers in the stagnant layers. Algae and diatoms when present in the bottom layers appear to arrive there only by settling down from above.

In this country the increase in color in stagnant bottom waters is noticed in practically every instance, and this is true to a greater or less extent of the odors of decay.

Comparatively little has been heard in this country of the increased power of impounded water to dissolve lead or objectionable fungus growths in bottom layers, but in Great Britain, as has already been stated, lead poisoning has been more or less of a practical matter. Indeed, in order to neutralize free carbonic acid in the water of the new Elan Valley Reservoirs of the Birmingham supply, it was found desirable to add lime at times. This has also been done at Burnley and elsewhere.

Heavy growths of Cladothrix and other fungi have been noted in several large reservoirs, particularly those of the Elan Valley works (Birmingham) and the Vyrnwy works (Liverpool) in Wales. Neither of these reservoirs was stripped, and Lake Vyrnwy was not even grubbed. Although in each case water is drawn from the top, these growths have caused deposits in tunnels and pipes leading from the reservoirs to the filters and materially reduced their carrying capacity. So far as known these fungi do not directly cause bad odors or tastes either by growth or disintegration.

REMEDIES FOR BOTTOM STAGNATION.—These are aeration, filtration and a combination of the two processes.

Aeration of surface supplies has been employed to a limited extent, only, either at home or abroad. The first notable American instance was in 1884, at the Hoboken reservoir of the Hackensack Water Co. (Trans. Am. Soc. C. E., 1885, Vol. XV., p. 139). The practice is growing of late, and has been applied to the bottom waters of the Upper Croton Reservoir, New York City, and the Pequannock reservoirs, Newark, N. J. Aeration saturates water with oxygen, aids in decolorization, reduces free carbonic acid, thus lessening the action of water on lead pipes, and is particularly effective in removing "substances like sulphuretted hydrogen which are present in the stagnant bottom layers of reservoirs." But while removing tastes and odors aeration cannot cope with conditions due to fungus growths and to "organic matter which after aeration is united more or less completely to a precipitate of iron."

Filtration does not appear to have been applied directly to stagnant bottom water. Such water resembles sewage and would have to be filtered intermittently or else be given preliminary treatment. The top waters of the newer Liverpool and Birmingham reservoirs show "marked effect of stagnation as regards higher amounts of color due to vegetable stain united with iron, and also as regards the presence of fungus growths." Filtration in open sand filters appears to give satisfactory results with these waters. The Elan Valley water, Birmingham, is given a rough preliminary filtration to prevent fungus growths in the conduits leading to the regular sand filters. Roughing filters are proposed at Lake Vyrnwy, Liverpool.

The remaining portion of this section of the report on the stagnant bottom layer is quoted in full, as follows:

*Report made to the Croton Aqueduct Board in 1859, by Dr. John Torrey (Trans. Am. Soc. C. E., Vol. XXI., 1889, p. 555). Wm. Ripley Nichols, algae growths in relation to filtration, Mass. State Board of Health, 1878. A Fteley, algae observed in Boston water supply in 1879, as above, 1879. Prof. W. G. Fowler, vegetable growths in drinking water, do., 1879. W. R. Nichols, tastes and odors of surface waters, Jour. Assoc. Eng. Soc., Vol. I., 1882, p. 97. Geo. W. Rafter, on fresh water algae and their relation to the purity of public water supplies, Trans. Am. Soc. C. E., Vol. XXI., 1889, p. 483. A. Fteley, discussion of Rafter's, paper, p. 518, as just above. The earlier discussions of tastes and odors were reviewed by W. R. Nichols, in his book on "Water Supply" (1883), and the writings of various authors on the biological aspects of the subject are reveiwed by Geo. C. Whipple in his "The Microscopy of Drinking Water" (1899). Also see reports Mass. State Board of Health, as follows: 1886, p. 6 (Brockton water supply); 1889, p. 28 (Springfield); 1890, Special Report, Part I., pp. 717-73 (F. P. Stearns and T. M. Drown on stripping, being the first adequate discussion of the subject, in the light of knowledge then existing); 1891-2-3, various references; 1895, Special Report on Metropolitan Water Supply (portion dealing with stripping the proposed Wachusett Reservoir); 1904, p. 144 (tabulated record of observations on taste, odor, etc., in 64 reservoirs). Biological, color and filtration studies at Chestnut Hill Reservoir, under the direction of Mr. Desmond FitzGerald, by G. C. Whipple, W. E. Foss and F. S. Hollis, Reports Boston Water Board 1890 to 1894, inclusive. Geo. C. Whipple, Allen Hazen, Geo. A. Soper and others, general discussion on "The Decolorization of Water." Trans. Am. Soc. C. E., Vol. XLVI., pp. 141-81. Data on conditions observed in the reservoirs built by Boston and by the Metropolitan Water Board may be found in the various reports of the Board named and of its successor, the Metropolitan Water and Sewerage Board.

Aeration and Filtration.—Decolorization.—In the stagnant layer of a deep reservoir fermentations take place, especially in summer, which result in the solution of considerable amounts of organic matter and also of iron in the ferrous state. This water can be aerated and filtered, thereby entirely freeing it from objectionable odors of decay, and utilizing the iron to a substantial extent as a coagulant to remove the color and other organic matter in the water, and so produce a water better and more acceptable in every way than could possibly have been obtained by filtration of the same water before stagnation and fermentation.

It is only within the past year or so that the practical significance of this proposition has been fully appreciated.

This action clearly accounts, in part, for the favorable results obtained in the filtration of the Ludlow Reservoir water by the new Springfield filters this year. Its presence was equally indicated in the experiments made some years ago at Springfield, under the direction of both the Massachusetts State Board of Health and Messrs. Gray and Fuller, but this explanation of the action was not made in their reports, and the reason for the extremely high degree of decolorization actually secured remained unsolved.

The same action has clearly taken place with the waters of some deep English reservoirs which are filtered. The very remarkable color removal obtained in these cases was noted by one of us in visiting these works in 1896, but no explanation of the way in which it came about was then reached.

The factors in the production of this condition are, first, an amount of oxidizable organic matter in excess of the dissolved oxygen in the water at the beginning of the season; and, second, the presence of a sufficient amount of iron.

There is always enough organic matter present in a reservoir to bring about this condition, except in large and very carefully cleaned reservoirs. It can be assumed that there will be organic matter enough under all ordinary circumstances.

The presence of iron would seem to be somewhat less certain. Generally the incoming water does not carry enough iron to be effective in this way. The soil in the bottom of the reservoir is sure to contain a large amount of iron and the fermentations taking place in it tend to the solution of this iron and to its extraction by the water. This seems to be ordinarily the chief source of iron in the stagnant water.

The iron may, however, come from the suspended matter of the incoming water. In a stream like the Esopus, where the water at times is fairly turbid, and where the turbidity of finely divided clay contains a considerable percentage of iron, this source is important and very likely sufficient.

As early as 1891 Dr. Drown recorded most of the underlying facts which have to do with this method of water purification, but he did not put them together and draw the logical conclusions, as he certainly would have done had he continued his studies. On p. 381 of the Massachusetts State Board of Health Report for 1891, he says:

> It is not uncommon to find iron in solution in considerable amount in the bottom layers of water in deep ponds, when the oxygen is exhausted. Insoluble iron oxide may, under these conditions, be reduced to the lower oxide, and go into solution. In such cases the water may be colorless when pumped up from the bottom but it quickly becomes turbid on exposure to the air, and the iron oxide separates out, on standing, as a red deposit.

This described precisely the conditions of the presence of iron and of its separation; but its coagulating effect in the practical purification of the water was not considered in the above article or in the paper of Dr. Hollis written during the following year.

Thus we find in these writings clearly expressed the ideas of the taking up of the iron, and its subsequent separation by aeration, as well as of the deodorization of the water by that same means, as already stated in this report. It remains only to draw the conclusion that the water which had been through this process was far better suited to complete purification by filtration than water which has not been through it, and that the resulting effluent would be cleaner, purer and better water.

SANITARY SIGNIFICANCE OF STAGNANT WATER.—So far as we are able to ascertain there is no well-defined sanitary significance to be attached either to the fungus growths which occur in the bottom stagnant layers of deep reservoirs or to the disagreeable tastes and odors found there, or to the organic matter from the incoming water or extracted from the bottoms and sides of the reservoir. The important question, therefore, is one of guarding against or eliminating disagreeable tastes and odors of decay and of obtaining a water of satisfactory appearance.

CONCLUSIONS.—We conclude from the available evidence that the effect of stripping the bottom and sides of reservoirs upon the quality of the reservoir water, as regards stagnation, is as follows:

(1) The stripping of the sides and bottoms of a reservoir will ordinarily prevent stagnation of the bottom layers for a period of years, the length of which depends upon various local conditions. In the Boston reservoirs this period does not seem to exceed from 10 to 20 years.

(2) Ultimately it makes comparatively little difference as to stagnation of the bottom layers whether the sides and bottom of a reservoir are stripped or not.

(3) By aeration and filtration of the bottom water of deep reservoirs there can be obtained a better quality of water without the benefits of stripping, than it is possible to obtain with the aid of stripping in the absence of aeration and filtration.

(4) In the absence of stripping substantially as good a quality of bottom water may be obtained, after aeration and filtration, as in the presence of stripping. In fact, as just stated, decolorization and purification are facilitated by the absence of stripping due to bacterial agencies which make some of the iron in the soil available as a coagulant.

(5) In view of the above, and as aeration and filtration will ultimately be required in order to obtain satisfactory results in this climate, present evidence and experience indicate that beyond grubbing a reservoir it is unwise to spend money for further removing organic matter from the bottom and the sides.

We may add that we are aware that materials obtained in stripping may be used successfully in building dikes, as at the Wachusett Reservoir, and that by so doing the net cost of stripping may be reduced. We also take into account the fact that any deep deposits of muck when sufficiently firm to carry it may be covered with sand at less expense than would be required for their complete removal. We will not enter into a discussion in this report of different methods of reservoir construction, but will simply state that in the preceding paragraph we have had in mind the net cost of stripping.

STRIPPING IN RELATION TO THE QUALITY OF TOP WATER, INCLUDING ODORS OF GROWTH AND DISINTEGRATION.

The evidence on this general subject presented 16 years ago by F. P. Stearns and T. M. Drown (Special Report Mass. State Board of Health, Part II., pp. 719-82) has been supplemented by additional evidence, with the assistance of Mr. Geo. C. Whipple. Data on 110 reservoirs in Massachusetts, 16 in Connecticut, 16 in New York State and a few elsewhere have been tabulated and plotted by Mr. Whipple, and foreign experience has also been considered. "The studies thus made," the report states, "have been singularly lacking in positive results," and even the general tendencies indicated are opposed by "many conflicting individual results." The most important conclusions drawn are:

> There are many conditions which affect the growth of organisms producing tastes and odors in reservoirs. Growths are the result of a combination of a number of favorable circumstances. Stripping reservoirs is one of the conditions which tends to influence the growths in a reservoir, but there are other conditions which exert as much influence as stripping, or, even under similar conditions, a much stronger influence.
>
> Generally to produce troublesome growths of organisms it is necessary that the reservoir should be seeded or infected with the organisms; that the temperature of the water should be suitable for this growth; that sufficient food supply for the organisms should be present; and that the water should be sufficiently quiet and free from physical disturbances to allow their development. The absence of any of these necessary conditions will keep the water free from growths, even though the other conditions are favorable.

The conditions affecting growth are considered under a number of heads.

Seeding is irregular in point of time, uncertain as to origin, and beyond control. The spores of organisms may be brought to a reservoir by the water from the drainage area or perhaps by the wind, and possibly one group of organisms may tend to prevent the development of another.

Growths of Organisms are temporary and may not be noticed or recorded. They probably occur in bodies of water not used for public water supplies oftener than has been supposed. They may develop in reservoirs or lakes used for public water supplies, but disappear before reaching the consumer. These facts, combined with the infrequency of microscopical examinations of water (rarely oftener than once a month, even in Massachusetts) suggest that many previous deductions on organic growths under various conditions are unreliable.

Other than Nitrogeneous Foods for growths of organisms are probably available (contrary to earlier ideas), recent studies indicating "that the carbon of organic matter, particularly in the form of free carbonic acid, plays an important part as a source of food for organisms." The practice of covering reservoirs which store water free from organic matter and from organisms, whether the water be from the ground or from filters, is necessitated by the deterioration of water due to organisms that develop rapidly in these organically pure waters under exposure to sunlight.

Foods for Organisms may be brought into reservoirs from their catchment areas, may arise from weed growths on the sides of reservoirs, may be supplied by past generations of organisms, or from sewage pollution.

Temperatures of Surface Waters are important factors in the growths of various organisms. Protozoa and diatoms may develop in winter, and diatoms and some forms of algae in the spring and fall, but a water temperature of about 70° F. is essential to the maximum growth of the blue-green algae which cause so much trouble in America. The freedom of British reservoirs from blue-green algae is probably explained by the fact that the temperature of the upper layers of these reservoirs seldom exceeds 65° F. and only exceeds 60° for short periods.

Winds and Agitation, if sufficiently violent, retard or prevent the growth of organisms.

Physical Features of Reservoirs, such as area, depth, volume as related to storage period, and soil conditions are next considered. *Area*, if large, increases wave action and is thus unfavorable to organic growths. *Depth*, on the whole is unfavorable to organisms. *Storage* for long periods is favorable to stagnation and stratification and is likely to be accompanied by exposure of bottom slopes, with a consequent growth of weeds. *Soil Conditions* affect the amount of organic matter that may be taken up by the stored water and also affect the growth of weeds when the slopes are exposed. This feature is discussed further on, under Ashokan Reservoir.

REMEDIES FOR BAD TASTES AND ODORS OF GROWTH AND DISINTEGRATION.—These are aeration, filtration, a combination of the two and, finally copper sulphate treatment.

Aeration is now recognized "as a powerful agent in treating waters suffering from tastes and odors of growth and disintegration." It reduces free carbonic acid, which is one of the foods for organic growths, and by agitating the water it kills or prevents the multiplication of organisms. Aeration of impounded waters will remove tastes and odors already in existence, and "will reduce but not necessarily remove satisfactorily the odors of disintegration and decay resulting from the organisms in the water at the time of aeration." Far more vigorous aeration is required to remove carbonic acid, tastes and odors than is required to saturate water with oxygen, and there are doubtless "some tastes and odors which could not be adequately removed by any practicable amount of aeration." Examples of the effect of aeration are afforded by Springfield and Holyoke, Mass., Newark, N. J., and Yonkers, N. Y.

Filtration for the reduction of tastes and odors has not been accepted as practicable until quite recently, partly from a lack and partly from a misunderstanding of data. The growing practice of covering reservoirs used to store filtered water, and of covering filters as well, and particularly the new data on aeration, are all favorable to the present adoption of filtration.

Aeration and Filtration Combined was first successfully applied to impounded water in this country at Reading, Pa., so far as the authors of the report are aware, following [some time after] tests made in 1897. At Springfield, Mass., tests with double filtration and aeration were made in 1901 to 1903. Since July, 1906, a four-acre filter plant has been in successful use at Springfield, but single intermittent sand filtration at a rate of 4,000,000 gals. a day is employed. Another recent example of a combination of aeration and (mechanical) filtration is afforded by Charleston, S. C. (Eng. News, 1906, Vol. LV., p. 636).

Copper Sulphate Treatment, while of practical benefit when judiciously used, "requires much more care" for its safe use "than appears to be realized by some," and "there are apparent limitations to its general use which are not fully appreciated at this time." The authors "do not

disposed to recommend" copper sulphate such a reservoir as the Ashokan, covering 12 square miles, particularly as "aeration and filtration, which are highly desirable for other reasons, will fully prevent any unsatisfactory results from algae growths."

CONCLUSIONS AS TO THE EFFECT OF STRIPPING ON TASTES, ODORS AND THE GROWTH OF ORGANISMS.—These are as follows:

(1) We agree at the present date with the conclusions of the late Prof. Wm. Ripley Nichols, who stated in a report on p. 89 of his book on "Water Supply," that "so far as our present knowledge goes there is nothing that can be done to exterminate the algae from ponds in which they occur." We further agree to his statement, already quoted, that stripping is no guarantee against troubles of the nature discussed in this report.

(2) The stripping of the sides and bottom of a reservoir has a well-defined tendency during the early life of a reservoir to guard against objectionable tastes and odors due to organisms. But this tendency is variable in its effect, depending upon a considerable number of other factors. Its effect may be beneficial for many years. In the Ashland and Hopkinton reservoirs objectionable tastes and odors were not noted until 15 or 20 years after they were put in service.

(3) Natural ponds and lakes having clean bottoms and sides give more trouble from growths of organisms at intervals than was formerly supposed to be the case. This fact is partly associated with questions of seeding the water and partly with the meagerness of available observations.

(4) The food obtained for growths of organisms from organic matter originally upon the bottom and sides of reservoirs is only one of various sources of food which will bring about these growths when other conditions are suitable, such as seeding, temperature and the requisite degree of quiet.

(5) Ultimately it makes comparatively little difference as to growths of organisms in a reservoir water whether the sides and bottom of the reservoir are stripped or not. This is due to the slow but steady elimination of organic matter from the bottom and sides of unstripped reservoirs by bacterial action, and to the equally slow and steady accumulation of organic matter resulting from growths of organisms in all reservoirs, whether stripped or not, in this climate.

(6) Aeration will greatly improve the quality of the reservoir water with regard to the removal of tastes and odors and for a comparatively small expense will do as much, and perhaps more, towards removing the effect of these growths than stripping will do towards preventing them.

(7) Filtration alone, as was believed some 15 years ago, is not wholly successful in removing bad tastes and odors, but when combined with aeration it affords, according to present information, the only effective and practical means of guarding the consumer against bad tastes and odors in impounded reservoir waters.

THE ASHOKAN RESERVOIR.

About one-seventh of the report is devoted to the specific problem of the Ashokan Reservoir, but it should be noted that all that precedes leads up to this part of the report, and that the general review of experience elsewhere was requested by Mr. Smith. This portion of the report, and the final conclusions, we give in full, as follows:

MAIN PHYSICAL FEATURES OF THE ASHOKAN RESERVOIR.

GENERAL FEATURES.—The Ashokan Reservoir will have a total capacity of about 120,000,000,000 gals., an area of about 8,300 acres, an average depth of about 45 ft. and a maximum depth of about 180 ft. Of the area within the flow-line, about 4,800 acres may be classed as stony upland, about 1,400 acres as meadow or alluvial land, and about 2,100 acres as soft, swampy material or muck. A plan of the reservoir site has been prepared in your office, showing the location of these classes of material, and also the wooded areas.

GEOLOGY.—It is of interest to note that the soil is to a large extent impervious, containing more or less rock-dust resembling clay, and comparatively little sandy or gravelly material. The rock is for the most part blue-stone.

DRAINAGE AREA.—The area tributary to the reservoir is about 255 square miles. It is largely of a mountainous character and forested. There are very few swamps, and the population is sparse.

CHARACTER OF SOIL.—Special studies have been made to locate the extent and depth of different kinds of soil on the sides and bottoms of the reservoir, and especially the swamp areas and mucky material which have been considered of special significance in this connection. This work has been carried on under the direction of Mr. Carlton E. Davis, Department Engineer. Analyses of large numbers of samples of soil have been made by the Chemist of Headquarters Department, Mr. Richard H. Gaines, to show the loss of ignition. These results have been tabulated and plotted in your office on plans of the reservoir site, to indicate the extent and character of the different kinds of materials. Lines have been drawn on these plans dividing the area into four classes, according to the loss on ignition of samples taken near the surface, as follows: Over 25%; between 10 and 25%; between 5 and 10%; and less than 5%.

SOIL EXTRACTION EXPERIMENTS.

At our request you have had certain experiments made at West Shokan to show the relative amounts of organic matter extracted from different soils and from soils differently placed. The result of these analyses and experiments, covering a period of about nine weeks, beginning early in September, have been useful in reaching conclusions as to the third proposition submitted to us. It will suffice at this time to state that the analyses and experiments have shown that the soil, generally of a clay-like nature, yields up its organic matter to water far more slowly than does sandy or gravelly soil. It is also shown that much more extractive material of an organic nature is obtained from surface soil (sod) containing about 12% of organic matter than from peat, containing over 60% of organic matter. This seems to be because the organic matter in the peat is of far less soluble character and has reached a practically stable condition when under water and out of contact with air.

The experiments have also shown that the greatest amount of extractive matter is obtained from the vegetation above the surface soil, where that exists—the amount of material extracted from such vegetation being materially greater than from even the richest soils devoid of such vegetation.

PROPOSED ARRANGEMENT OF THE ASHOKAN RESERVOIR.

DIVISION EMBANKMENT.—We understand, first, that the dam-site at Olive Bridge will be used in preference to the lower site; second, that the reservoir will be divided near its middle into two parts, which we shall speak of as the western and eastern basins.

WESTERN BASIN.—The western division of the reservoir, upon Esopus Creek, is smaller in area and capacity than the basin on Beaver Kill. Its area when filled will be about 3,500 acres; its capacity, 48,000,000,000 gals.; its maximum depth, about 180 ft.; and its average depth, 42 ft. Nearly all of the watershed area is tributary to it, and water will be taken ordinarily from this division to maintain the supply. There is but little swamp area upon the bottom of this basin. The watershed is unusually clean and practically free from swamp areas. The Esopus Creek water entering it is almost entirely free from color and peaty matter, but it is moderately turbid at times. The clay-like soil forming the bottom of the reservoir gives up organic matter to the water much more slowly than a sandy or gravelly soil would do. The conditions in this respect are radically different from those in Massachusetts.

EASTERN BASIN.—The other arm of the reservoir, on Beaver Kill, is larger and slightly deeper. Its area will be about 4,800 acres; its capacity, 72,000,000,000 gals.; and its average depth, 47 ft. Between 1,700 and 1,800 acres, or about 35% of its area, are swampy. The watershed tributary to this basin is comparatively small. The water of Beaver Kill is peaty and yellow in color, and the water in this basin will have more color and less turbidity than that in the western basin. The overflow from the western basin will be through the eastern basin, and this will tend to replace the water in it with water free from peaty matter and color.

ASSUMPTIONS AS TO OPERATIONS.—We assume that the western basin will be used to maintain the supply ordinarily, and that it will be sufficient to furnish all the required storage in all but the very driest years. On the latter occasions, particularly when the reservoir is depended upon to maintain the supply over a dry period exceeding one year in length, the eastern basin will be drawn upon as may be required.

CONCLUSIONS AS TO STRIPPING THE ASHOKAN RESERVOIR.

From experiences with stripped and unstripped reservoirs, it follows that whether this reservoir is stripped or not there is no surety that the water drawn from it can be delivered regularly to consumers in a condition suitably free from small vegetable and animal life and their attendant products. In other words, to deliver the Ashokan water to the consumers in a thoroughly satisfactory condition at all times, it is necessary to give the water some form of treatment, by aeration or by filtration or otherwise, after it leaves the reservoir and before it reaches the consumers.

LIMITATIONS TO RESERVOIR TREATMENT.—The facts above stated lead to the further conclusion that, whatever may be done in regard to treating the bottom and sides of this reservoir, it is obviously not economical or advantageous to spend money for such treatment beyond a point where it is clear that additional expenditures may not be more advantageously applied in other ways in order to deliver to the consumers a satisfactory water.

KENSICO RESERVOIR.—Up to this point we have discussed the Ashokan Reservoir as if the water from it were to be supplied directly to the city. This, however, is not the case. It is proposed to build a reservoir at Kensico holding about 50 days' supply.

The question is, therefore, not what effect stripping would have on the quality of the water leaving the Ashokan Reservoir, but what effect the stripping of the Ashokan Reservoir would have upon the quality of water leaving the Kensico Reservoir. Clearly the comparison of the cost of stripping with the advantages to be derived from it must be made on the latter basis. This will be substantially true, even though the Kensico Reservoir is not used at the outset; for in that case the first water drawn from Ashokan will be used through the present Croton Reservoir, in which case the supplementary storage at Croton would substantially have the same effect as the supplementary storage at Kensico.

The effect of this method of handling the water is of vital importance, because tastes and odors in water, whether due to stagnation and putrefaction or to growths and disintegration of organisms, are transient phenomena. They come and go with changing conditions and seldom last continuously for long periods. In no event can it be supposed that the substances causing a particular taste or odor will pass unchanged through the aqueduct from Ashokan to the Kensico Reservoir, through it and thence to the city. All of the tastes and odors existing in the Ashokan Reservoir will be eliminated from natural causes before the water reaches the city. If tastes and odors appear in the water at the city, they will be the result of conditions in the Kensico Reservoir rather than of the conditions in the Ashokan Reservoir. The suppression of growths in the Ashokan Reservoir would, therefore, have only an indirect effect upon the quality of water leaving Kensico.

Growths in the Ashokan Reservoir may serve to seed the Kensico Reservoir, and they may contribute indirectly to growths in it, due to products of their decomposition furnishing a food supply for subsequent growths. Undoubtedly growths in the Ashokan Reservoir would in this way contribute somewhat to growths and to stagnation in the Kensico Reservoir. The most important food product transferred from Ashokan to Kensico with the water would probably be carbonic acid, and this can be largely removed by aeration of the water as it leaves Ashokan.

We can find no certain or well-defined evidence that the stripping of the Ashokan Reservoir will change the character of the water leaving Ashokan, so as to materially improve the character of the water leaving Kensico. The reasons for believing that there may be some such improvement are remote and speculative, and are not such as to justify the great expense of stripping the Ashokan Reservoir.

COMPARATIVE COST OF STRIPPING.—The cost of stripping the Ashokan Reservoir would be very great, possibly as much as $5,000,000. Aeration of the water as it leaves the reservoir will do as much, if not more, to remove the tastes and odors as stripping would do to prevent them, and the cost of aeration would be only a small fraction of the cost of stripping.

For the cost of thoroughly stripping the Ashokan Reservoir it would be possible to build a filter plant to filter all the water that could be obtained from the Esopus watershed; and a filter plant between the Kensico Reservoir and New York City, following aeration, would be far more efficient in preventing tastes and odors and in otherwise improving the quality of the water, as supplied to the consumers, than stripping could be, even under the most favorable conditions. We are firmly of the opinion that materially better results than those due to the stripping of the Ashokan Reservoir could be obtained by such aeration and filtration, as regards either the quality of the purified water or the cost of purification.

RECOMMENDATIONS AS TO TREATMENT OF THE ASHOKAN RESERVOIR.

Our conclusions, after careful deliberation upon this matter, in the light of experience now available from various large city water-works, lead us to the following recommendations.

(1) CLEARING AND GRUBBING.—Cut all trees and bushes close to the ground over the entire area of the sides and bottom.

(2) BURNING VEGETATION.—Burn all grass, weeds and shrubs and see that this is done shortly before the areas are flooded. In other words, do not allow the water to flood any areas on which extensive growths of weeds have occurred since the original preparation of the area.

(3) PREPARING THE SHORES.—Around the shore of the reservoir, to a vertical depth of at least 20 ft. below high water, remove all stumps and, so far as necessary, roots and other matters which might become exposed by continued wave-action; and leave the surface with even slopes, so that the shores will be maintained in a presentable condition when the water is drawn down. We do not think it is necessary to spend a large amount of money in this preparation. The wave-action will tend to clean it and accomplish the desired results, but some extra attention should be given to it with reference to its appearance when exposed, and also to prevent as far as possible the leaving of enclosed shallow areas which might serve as places where the spores of organisms would remain and serve as centers of infection when conditions in the reservoir became favorable.

(4) PREPARING THE BOTTOM.—After removing all the top vegetation from the swamp areas, which can be done by cutting it off close to the surface and burning, careful examination should be made for places where the surface "crust" is so loosely attached to underly-

ing soft material that it might rise after the reservoir is full. We gave this question some attention when examining the swamps, and their surfaces, wherever we have seen them, are such that this factor does not appear to be of much importance here. However, experience elsewhere indicates that it should be given further attention.

(5) EACH BASIN TO HAVE OUTLET.—The separation of the reservoir into two parts, with outlets so that water may be drawn from either or both basins into the aqueduct, seems advantageous to us.

(6) DRAW AT ANY LEVEL.—We recommend that the reservoir outlets be arranged so as to permit water to be drawn from any desired depth.

(7) AERATION.—Arrangements should be provided to aerate thoroughly all the water passing from the reservoir to the aqueduct, except perhaps at times of extremely low stages of water in the reservoir. This can be accomplished by fountains and basins, or other effective appliances to make available the head of the water in leaving the reservoir for bringing it in contact with air to remove the gases which produce tastes and odors and which result from putrefaction in the stagnant layer and odors from the growth of organisms in the water; and also the carbonic acid which otherwise might serve as a food for further growths in the Kensico Reservoir.

In making the foregoing recommendations we desire to state clearly, that we consider,

First, that the stripping of the Ashokan Reservoir in itself will not sufficiently prevent tastes and odors so as to allow water of satisfactory quality to be obtained from it at all times;

Second, that aeration at a small fraction of the cost will do fully as much in removing tastes and odors as stripping would do in preventing them;

Third, that water of perfectly satisfactory quality can be obtained by aeration and filtration;

Fourth, that this result can be just as certainly and fully accomplished in this way if the Ashokan Reservoir is not stripped as if it is stripped.

It is certainly more important to consider the question of the quality of the water leaving the Kensico Reservoir than that of the water leaving the Ashokan Reservoir. In accordance with your instructions we shall report upon the treatment of the Kensico Reservoir in a subsequent communication after further local data are available.

COMBINATION CONCRETE, BRICK AND STEEL SHOP CONSTRUCTION: EL PASO & SOUTHWESTERN RY.

The El Paso & Southwestern Ry. System, owned by the Phelps, Dodge & Co. interests of New York City, comprises some 883 miles of standard gage railways, engaged chiefly in serving several copper mines and smelters located in Mexico, Arizona, New Mexico and southwestern Texas. The system is of recent development and is carrying a rapidly growing traffic, to serve which it has recently finished at El Paso, Texas, about the geographical center of its lines, a new yard and shops. There are in the yards, which cover an area of about 64 acres, the following principal structures: A 21-stall roundhouse, machine shop, smith shop, mill building, paint shop, store house, power house, oil house, coaling station and a set of underground concrete fuel-oil tanks.

While some of the buildings are of ordinary steel frame construction, most of them are of a peculiar combination construction, having foundations, main columns, sills and lintels of concrete, walls of brick and structural steel roofs and girders. A typical building is illustrated in Fig. 4.

All trenches and pits for the foundation footings and walls extend down into a deep bed of fine, clean sand. The excavations were thoroughly slushed with water before any concrete was placed, the result being ideal foundations of great uniformity and sustaining power, in which settlement, if any, will be evenly distributed throughout. The pressure on the sand is limited to one ton per sq. ft. for moving loads, and two tons for static loads. There is no doubt that these could have been increased 50% without harm, but the necessary widths of footings to carry the superstructure dimensions of walls, etc., generally required but slight additional widths to keep within the above maxima. In the case of isolated piers carrying heavy loads, wide and comparatively thin reinforced footing slabs were used, resulting in economical foundations. The result of these excellent foundations is seen in the total absence of any settlement cracks or any appreciable settlement in the structures. All foundation footings and walls are exclusively of 1-3-5 concrete. In engine pits, transfer pit, ash pit, turn-table pier, etc., subject to moving loads, the concrete footings and walls are reinforced throughout, resulting also in the absence of any cracks or appreciable settlements.

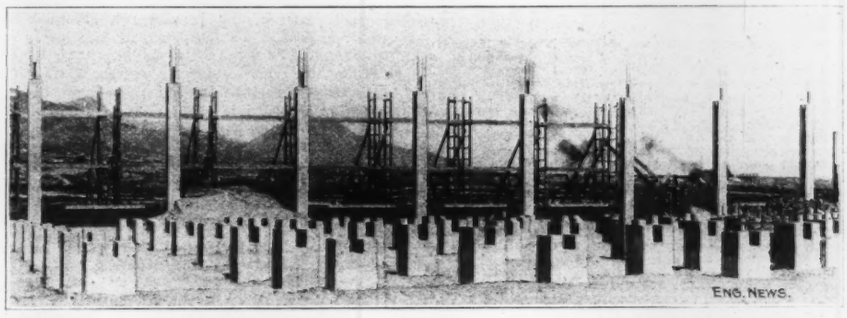


FIG. 1. BEGINNING WORK ON SHOP BUILDINGS FOR THE EL PASO & SOUTHWESTERN RY. SYSTEM, AT EL PASO, TEXAS.

In the foreground are concrete piers molded to receive wooden floor girders. Farther back, reinforced concrete columns with steel reinforcement projecting at top. Interior angle punched ready for connection to roof trusses. At rear, forms are in place for columns.

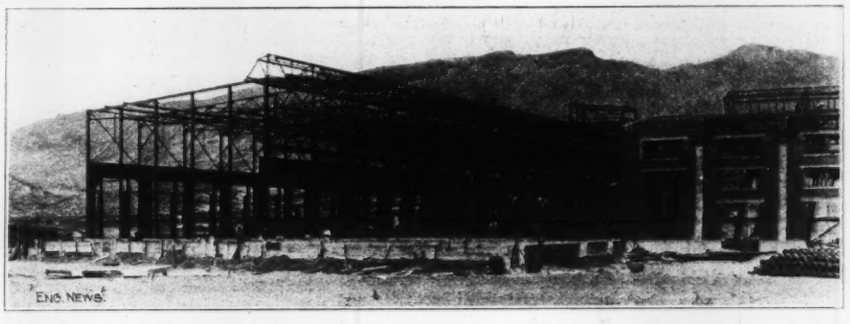


FIG. 2. STEEL FRAME OF MACHINE SHOP AND PART OF REINFORCED CONCRETE BLACKSMITH SHOP.

On blacksmith shop, method of finishing top of concrete columns after connection to roof trusses is shown.

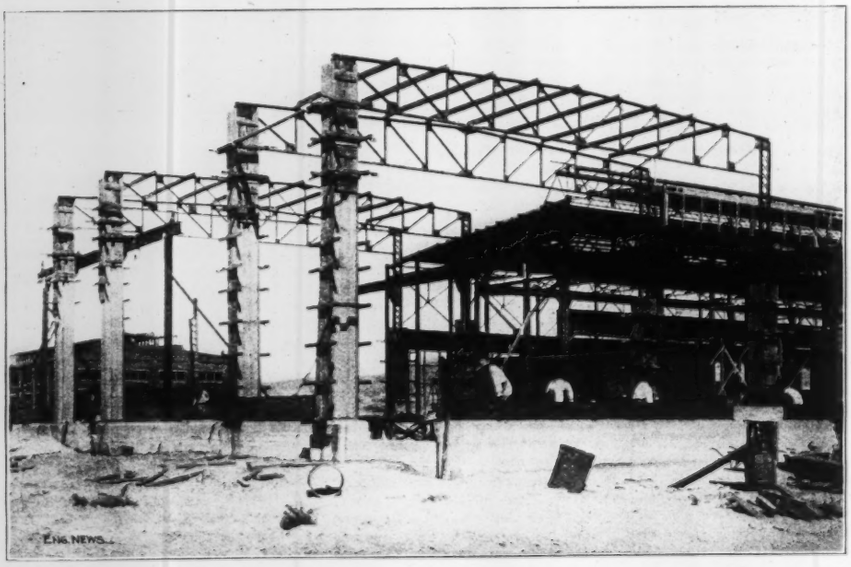


FIG. 3. VIEW OF POWER HOUSE ON JUNE 4, SHOWING SECOND METHOD OF BUILDING REINFORCED CONCRETE COLUMNS.

Latticed steel column put in place first.

In the construction of the buildings with concrete columns three methods were employed, improvement being made as the work progressed and experience developed.

The columns were first erected as shown in the background in Fig. 1, and reinforced with four ⅞-in. rods in the corners of the section. In addition a vertical angle was run throughout the length of the column and properly punched for the riveted connection to the truss at the top. The concrete was then carried to the bottom chord of the roof truss (see front row of columns, Fig. 1), the roof truss connected to the angle and the reinforced column then carried to the top of the truss, as shown in the two columns on the right-hand side of Fig. 2.

It was found extremely difficult, however, to maintain the alinement of these columns in two directions, since they had to fit not only the length of the truss across the span but also the lateral connections between the trusses.

On account of this difficulty, the first method was used only on one building, a new scheme being used on the remainder. It consisted in first erecting the roof trusses on light latticed steel columns containing metal in quantity and position sufficient for the reinforcement, and

ng anchor bolts extending to the bottom of concrete foundations. This is shown in Fig. After the trusses were so erected and the connection made, it required only ordi- care to build up the concrete around the expeditiously and economically and with

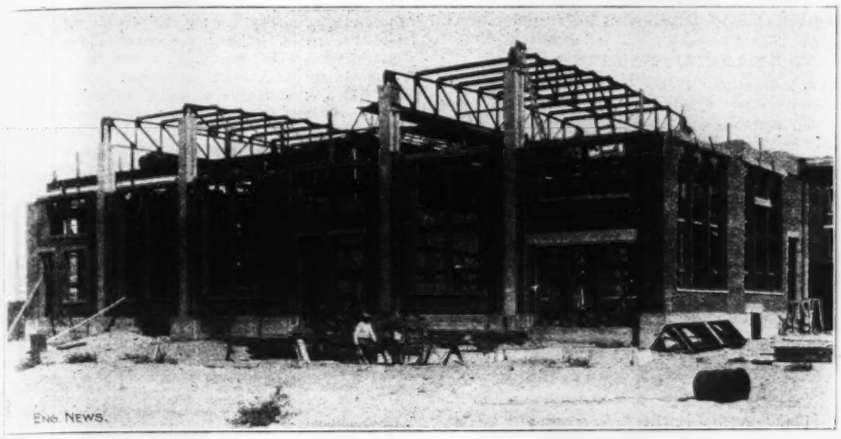


FIG. 4. VIEW OF POWER HOUSE ON JULY 3.

absolute certainty that the tops of the finished columns would be in correct position.

On each side of all the concrete columns a groove was formed, into which the brick walls were morticed. In most of the buildings, the brick walls were laid up after the column was finished, but in one building after the steel was all erected, the brick walls were next built with the required tenons on the faces to connect to the concrete columns. The latter were then molded in place around the steel and brick. This method required very little form work and gave the best union between the brick and concrete. Inasmuch as the brick walls were laid in cement mortar, the construction as a whole is very strong and rigid.

The reinforced concrete lintels, some of which are 12 ft. long, were cast in place, but the sills were cast separate on the ground and set afterward.

The fuel oil tanks were built underground out of reinforced concrete. They are covered with flat reinforced slabs, whose tops are about four ins. above the top of an adjacent yard track, and will take oil directly from the cars through an 8-in. receiving pipe opening upward in the middle of the track.

Before these tanks were built, a small test tank of 1-2-4 concrete was built and filled with fuel oil to determine the penetration and effect of the oil on the concrete. At the end of nine months this test tank is still full of the

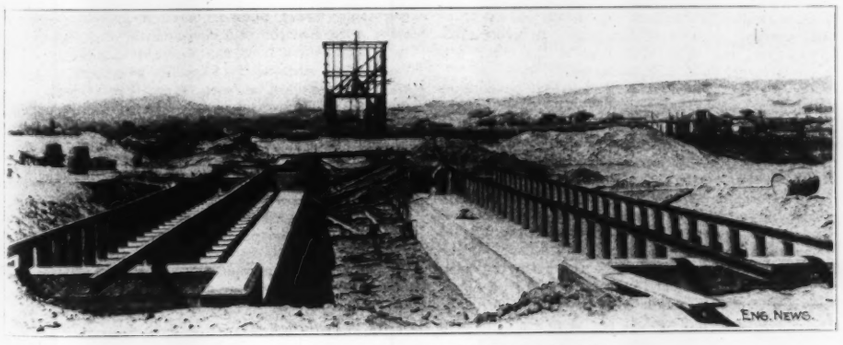


FIG. 5. FIREPROOF CINDER PITS IN YARD.
A depressed track for ash cars was afterward laid between the pits.

original oil, the level of the latter having fallen in that time only ⅝ in., due doubtless to evaporation. The tank proved absolutely tight, the oil having penetrated and discolored the concrete less than ½-in. The latter is apparently still entirely sound and uninjured.

Fig. 5 illustrates a novel form of cinder pit and erected under the direction of Mr. J. L. Campbell, M. Am. Soc. C. E., Engineer of Maintenance of Way for the railroad, with Messrs. Frank Powers and Sorenson U. Morgan of El Paso as contractors.

erected in the yards. It will be noticed that short concrete columns are used to carry the rails across the pit, thereby avoiding all liability of destroying the pit by a chance fire from the cinders.

The buildings here described were designed

COMMENTS ON SOME FRENCH TESTS OF WATER METERS.*

By Clemens Herschel,† M. Am. Soc. C. E.

About one hundred meters, representing 18 different kinds, were tested in 1905 by the government institution named in the foot note (founded in 1903). This report is the result, if result it may be called, there being reasons, as will presently appear, why all the work done may for the present be considered as unrevealed, latent, and useless. With a fine scientific marshalling of data, no account was made of the diameters of inlet and outlet orifices in the classification of the meters. Instead, they were rated or named in accordance with their discharge under the uniform loss of head or pressure of about 33 ft., called the "characteristic discharge."

When new, the meters were adjusted to register exactly right at one point at least of the discharge curve, and were then tested from zero discharge up to the characteristic discharge, which includes a determination of the discharge at which the meter begins to register; and were then compared, the one with the other, by tenths and other decimals of characteristic discharge.

After running 1,000 hours, and again 2,000 hours, at 1/10 of the characteristic discharge, the meters were again tested in the same manner as when they were new; which constituted the "endurance" tests.

Says the report under consideration:

It is evident, for discreet reasons readily understood, that it has not been possible to give the names of the meters which have been tested in the Laboratory, or even the names of their makers.

Instead of this, the meters have only been divided into three general classes: Class I., piston; Class II., disk; Class III., velocity or inferential meters. So that, as a net useful result of all the tests, we have only a scientific, not a practical, comparison of these three classes of meters; on the score of sensibility (least rate of flow metered); of accuracy; and of durability; a scientific result, and not a practical one, because not so much as an allusion is made to the net selling price or other practical data relating to the several meters which were tested.

It is the business of a civil engineer, as distinguished from that of a *savant*, or learned man, to work with usefulness to mankind as the direct, not indirect, aim of his work and endeavors, and this report thus falls outside—we need not now discuss whether below or above—a classification which would place it among the results of the work of civil engineers.

The American counterpart, and contrast in certain particulars as well, of this product of a government institution of France, is furnished by the paper on "The Accuracy and Durability of Water-Meters," read before the American Society of Civil Engineers on Feb. 1, 1899, and by the discussion which followed the reading of that paper; the whole printed as No. 848 of the Transactions of that Society. The writer knows of no further published reliable information concerning water meters manufactured in the United States than is contained in this paper, and in the discussion upon it—the latter quite as valuable as anything to be found in that number of the Transactions—although seven years have elapsed, and great changes have taken place in the use of water meters since then, under the influence of this and other related papers published by water-works engineers and superintendents in the United States.

In September, 1895, the writer published in the journal of the New England Water-Works Association (Vol. X.) the results found by him in the test of a certain seven meters. On account of his having tested only seven meters (to be compared with the test of one hundred such by the government establishment here reviewed), the writer did not give the names of the meters, but merely designated them 1, 2, 3 to 7; intending, if possible, some day to continue the series. As a consequence, and as quickly appeared, these tests thus published were of no use to anybody except to those who had made them; and it was with great satisfaction that the writer could take the occasion of the reading of the Paper No. 848, four years later, to break the seal of secrecy and also to sanction, and in every way possible to aid in, the publication by his then assistant, Mr. J. Waldo Smith, M. Am. Soc. C. E., now Chief Engineer of the New York Board of Water Supply, of all the facts discovered during the tests of these seven meters. This for the first time gave these tests value from the standpoint of the civil engineer, and clearly showed the error of having kept these tests secret, or of keeping any such tests a secret.

This is a world of the survival of the fittest, and it is no part of the duty of engineers, least of all of government engineers, to shield the life of the mechanically unfit among machines, and at the same time to keep secret the merits of the mechanically perfect or well fit. They need not give opinions, except when asked to do so by clients or superior officers; but to give out the facts found as the result of experiments is the duty of engineers who have any "esprit de corps," and should be made the duty of government engineers by the government.

In France such work appears to be done mainly at government institutions, and could, as suggested, be made by government order of great value to the community. In this country we are dependent on private initiative for the same kind of work.

*Based on "Essais de Compteurs d' Eau" (Tests of Water Meters). By A. Perot, Director of the Testing Laboratory, and H. Michel-Levy, Assistant, Conservatoire National des Arts et Métiers (National Institute of Arts and Trades). Paris, 1906.

†Civil and Hydraulic Engineer, 2 Wall St., New York City.

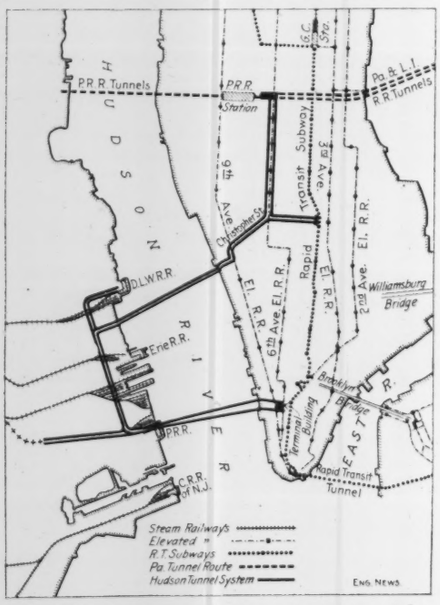
Generally speaking, the first named method is more richly endowed with means to reach the end sought, although an association of private means will rank a close second. The writer has therefore suggested that some one of our waterworks associations should do the like kind of work; following the example of the Pennsylvania Railroad, the Master Car Builders' Association, the American Association of Railroad Master Mechanics, the New England Association of Railroad Superintendents, the Manufacturers' Mutual Fire Insurance Companies, and many more such bodies, which habitually conduct tests for the benefit of their members and of some portion, at least, of the general public.

Thus at minimum expense could be served the common good; and the published results of complete experiments of this class become possible; while without a union of endeavor of this sort, this might for a very long term of years remain impossible.

THE RAPID TRANSIT TUNNELS UNDER THE HUDSON RIVER AND THE CHURCH ST. TERMINAL.

In addition to the several railway tunnels now being driven under the rivers around New York City, there are in process of construction two twin tunnels to accommodate interurban traffic between the Jersey towns and Manhattan. The location of these tunnels is noted on the accompanying map.

The two southern tunnels will extend from Cortlandt and Fulton Sts., Manhattan, to Montgomery St., Jersey City, the north one carrying



The Rapid Transit Tunnels Under the Hudson River.

Map showing the location of the new tunnels and subways now being driven for interurban service between Jersey City and Manhattan.

west-bound traffic and the south tunnel the east-bound. The subway continues westward from the Jersey City shore for about ¾ mile to Brunswick St., where it emerges from the ground and the lines continue on the Pennsylvania R. R. tracks to Newark. From the Manhattan terminus a foot passage will be built under Dey St. to meet the Manhattan subway at Fulton St. station.

The two northern tunnels will run from 15th St., Jersey City, to Morton St., Manhattan. From Morton St. the bore will continue as a subway on line of Christopher St. to Sixth Ave. At this point the subway will split in two parts, one going along 9th St. to meet the present Rapid Transit Subway at Astor Place, the other continuing up Sixth Ave. as far as 33d St., where a large station will be built.

The north tunnel is the famous old Hudson River Tunnel, work upon which was begun in 1878, stopped in 1880 after about 1,200 ft. had been built; recommenced in 1890 and again stopped in 1892 with a total of 3,000 ft. finished. The new work was started in 1902 and has now penetrated the entire distance under the river with work at present going on under Sixth Ave.

On the New Jersey shore there will be a transverse tunnel extending under the tracks of the Pennsylvania, Erie and Lackawanna railroads, with entrances at their various stations, and joining the Jersey termini of the rapid transit tunnels.

TERMINAL BUILDINGS.

As an indication of the tendency toward centralization now becoming necessary in the economic development of a large city, the office building to be built at the Church St. terminal, Manhattan, is of peculiar interest. This building, which is carried over and under Dey St. by bridges and sub-basements, will be in two parts, known as the Fulton and Cortlandt buildings. It will be 22 stories high with 4,000 office rooms and a cubical contents of 18,150,000 cu. ft., nearly three times the size of the present largest office building in New York.

The peculiar strategic position of the building will be seen when it is noticed that it commands a covered and protected line from all of Manhattan Island by way of the subway and from all the Jersey and West Shore suburbs by way of the various railroads coming into Jersey City. As an example of its future use a project is on foot to locate all of the New York offices of one of the large trades interests in this office building, and to build somewhere out on the Jersey end of the line large store and exhibit houses to which a prospective customer may be taken in but a few minutes from the main offices.

The tunnels are now being built by the Hudson & Manhattan R. R. Cos., with Mr. Chas. M. Jacobs, M. Am. Soc. C. E., as Chief Engineer and Mr. S. V. Davies, M. Am. Soc. C. E., Deputy Chief Engineer. The new office building is being built by the Hudson Companies, with Messrs. Clinton & Russell as architects.

COMPARATIVE MERITS AND COSTS OF THE MULE AND THE ELECTRIC LOCOMOTIVE FOR MINE HAULAGE.*

By W. F. Murray.†

It is not my object in this sketch to endeavor to organize a crusade against the noble servitor of mankind, as the mule has been called, but to try to show the chief advantages that may be derived from using mechanical haulage. Gathering locomotives in the Western States are not as yet used very extensively. However, it will not be many years before the various companies will install such a system in order to reduce cost of haulage, and to get better results.

The chief advantage in using mules lies in the fact that the mule can enter any portion of the mine unhindered, while the locomotive cannot leave the trolley, except by means of the cable-reel device. Another fact worthy of consideration is the difference in weight of the rails that may be used in each system; for mule power, steel as light as 16 lbs. can be used, while in other systems it is not advisable to lay less than 35-lb. rails. Also with locomotives an additional expense must be incurred, in bonding the rails. In using electric locomotives, the chief advantage is that they will haul a much larger load, and make better time.

With the present system of gathering coal from "face workings" in rooms or headings by mules, the limiting condition to the capacity of the haul is generally the lack of sufficient power to pull the cars; such a condition does not exist with the locomotives, as they are built to haul the heaviest car that can be used in a mine, and on reasonably steep grades. To be able to do considerable work, a mule should be fairly large, but in some of the low-vein mines of to-day, the use of even the smallest mule is impossible, on account of the low roof. For such mines as these the gathering locomotive would be an excellent investment.

The quantity of air required by the laws of some States is specified as 100 cu. ft. per man per min., and an additional 500 cu. ft. per animal per min. is stated. By this we see that a mule requires five times as much air as a man, so that by doing away with one mule, enough air would remain for an additional five men.

A much better roadway can be maintained by using locomotives, as the constant pounding of the mules' hoofs tends to make a rough roadbed and forms holes between the ties where the water collects, instead of running off, and makes nasty mud puddles; the mule also cuts the ties in two in the center, which makes frequent expense to replace.

The average active life of a mine mule is from seven to ten years, and as a company continually need a good supply of reserve mules on hand, because of accidents which are numerous, this means a considerable expenditure of money keeping the idle animals. A good locomotive should last, with occasional repairs, 25 years.

One of the greatest hindrances to the use of electricity is the danger of coming in contact with the naked wire, which often results in death; on this account the laws in several States prohibit using more than 250 volts. However, in the course of time men working underground become so accustomed to the wires that we very seldom hear of a death resulting from this cause.

The following figures show a comparison of cost between mules and an electric locomotive at a mine where 14 mules were replaced by one locomotive. The output of the mine averages 1,500 tons per day for 245 working days per year. The cars weigh 2,400 lbs. empty and hold 3,600 lbs., making a total weight of 6,000 lbs.

Mule Haulage.	
14 mules at $180.00 each	$2,520.00
14 sets of harness at $25.00 each	350.00
Total	$2,870.00
Interest and Depreciation.	
20% depreciation on $2,870.00	$574.00
6% interest on $2,870.00	172.20
Total	$746.20
Working Expenses for 245 Days.	
14 mules feeding, shoeing, repairing harness and care at 50c per mule per day	$1,715.00
6 drivers at $2.80 per day	4,116.00
Total	$5,831.00
Total working expense	$5,831.00
Total interest and depreciation	746.20
Grand total	$6,577.20

Fifteen hundred tons per day for 245 days = 367,500 tons per year at a haulage cost of $0.0179 per ton.

Electric Haulage.	
Engine, locomotive, boiler and generator	$9,000.00
Switches, insulators and wire	1,200.00
Cost of erecting, etc	1,000.00
Total	$11,200.00
Interest, Depreciation, etc.	
Interest at 6% on $11,200	$672.00
Depreciation on boiler, engine, etc., at 9%	810.00
Repairs on boiler, engines, etc., at 9%	810.00
Depreciation on switches, wire, etc., at 5%	110.00
Repairs on switches, wire, etc., at 5%	110.00
Total	$2,512.00
Engineer power house at $75 per month	$900.00
Motorman at $2.80 per day	686.00
Oil and waste	100.00
Nipper on motor at $1.50 per day	367.50
Sand	50.00
Total	$2,103.50
Total operating expense	$2,103.50
Total interest and depreciation	2,512.00
Grand total	$4,615.50

Fifteen hundred tons per day for 245 days = 367,500 tons per year. This makes the haulage on each ton of coal, where electric locomotives are used, cost $0.0126 per ton. These figures, taken from an actual case, show a considerable difference in favor of electric haulage. The cost of installing mechanical haulage is greater than when a mine is supplied with mules; however, when we consider the cost of erecting a stable and the great loss due to mules killed in accidents, the initial expenditure is not so favorable to the use of mules.

*Condensed from "The Engineering and Mining Journal."

†Engineer with Victor Fuel Company, Denver, Colorado.

A FALLING CAGE in the shaft of the Breese-Trenton Mining Co., Breese, Ill., killed six miners, Dec. 22. The cage had been lowered about 300 ft., when something went wrong with the hoisting machinery and the cage dropped the remaining 100 ft. to the bottom of the shaft, wrecking the timbering and killing the six men being lowered to begin the day's work.

CHAINS ON THE WHEELS OF HEAVY AUTOMOBILES are ruining the roads in Central and Riverside Parks, according to the report of the Park Commissioner of New York City. The damage done is serious. On many of the drives one can see where ruts have been worn, especially on the curves where the gravel has been torn by skidding wheels. Roads which before the advent of automobiles were repaired once every five years now require repairing every two years. The Commissioner recommends an ordinance prohibiting the use of chained wheels on park roads and also limiting the roads on which the heavy sight-seeing autos may travel.

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Stripping the surface soil from the site of impounding reservoirs is a Massachusetts refinement in water-works practice, confined almost wholly to Boston and vicinity. While generally recognized by engineers, of late, as a desirable precaution against tastes and odors, in the stored water, stripping has not been widely adopted.

This failure to put an accepted theory into practice has been largely due to the heavy cost of stripping large areas and to the general backwardness of the country in appreciating the value of pure water—using "pure" in a broad, inclusive sense. It is not surprising that communities which drink water continuously polluted with sewage, as hundreds of American cities still do, should be slow to take steps against possible future occasional troubles with tastes and odors from impounded waters. In Massachusetts, it should be noted, protection against sewage pollution and typhoid infection came before much attention was given to far-looking measures to prevent disagreeable tastes and odors.

With the example of the city of Boston and the Boston Metropolitan Water Board before it, and particularly in view of the immense sums of money spent by the latter body for stripping the site of the Wachusett Reservoir, it was to be expected that the New York Board of Water Supply would give serious consideration to the question of stripping its proposed 140,000,000,000-gal. Ashokan Reservoir. This it did by referring the whole question to Messrs. Allen Hazen and Geo. W. Fuller, M.'s Am. Soc. C. E. The exhaustive report of these engineers, which is abstracted at length elsewhere in this issue, will take its place as a classic in water-works literature. It is to be hoped that it will be made generally available by publication in pamphlet form.

It is unnecessary to dwell here upon the contents of the report, further than to call attention to the fact that its conclusions against stripping are based on evidence not available until recently; in fact, first brought together in clear and convincing form by Messrs. Hazen and Fuller in this report. The trend of opinion and practice, however, has been leading towards just such general conclusions: not alone as regards stripping, but also as to measures for ensuring safe and satisfactory water supplies. We have in mind the rapid growth of the idea that the best way to spend money to ensure the hygienic and esthetic qualities of water is to place a modern purification plant between the open or air-exposed portion of the water supply system and the water consumer. Experience shows that it is well-nigh impossible to prevent infection of even sparsely settled drainage areas or to make sure that bad tastes and odors will not develop in water from such areas if exposed to the sun in large reservoirs. Moreover, the standards for potable water are constantly being raised, the growth of the population of the country demands increasing quantities of water and is at the same time multiplying sources of human contamination.

Even as late as the adoption of plans for the Wachusett Reservoir, water filtration on the large scale demanded by American cities was problematical, but with the recent construction of filtration plants with capacities running from scores to hundreds of millions of gallons no water supply is too large or too difficult for purification. As we have often said, the time is sure to come when a surface water supply not subjected to filtration will be proscribed in America, as it has long been in Europe. The report by Messrs. Hazen and Fuller and subsequent developments of the New York water supply will hasten that day.

The latest break of the Colorado River into the Imperial Valley and down to the Salton Sea assumes a more serious aspect with every addition to the news concerning just what happened and what may be expected in the future. Each of the attempts thus far made to close the break (Eng. News, Dec. 27, 1906,) called for more extensive closure works than had been necessary before, the sixth and latest attempt including the construction of some ten miles of levee. It is now apparent that this levee must be of no ordinary design and construction if the river is ever to be held in its old channel.

Particular attention may be directed to the menace presented by the new river channel, which has been rapidly cutting itself back through the light, deep alluvial deposit of the Salton Basin, growing deeper and deeper with each step until at a distance of some 70 miles from the Salton Sea, and perhaps 30 miles from the river proper, the new channel has a sudden fall reported as 80 ft. in depth. At times, we are informed, this cut has proceeded at the rate of nearly a mile a day. Inasmuch as there remain but say 90 days at most before the recurrence of the spring floods, quick action must be taken or the whole Imperial Valley may be doomed for generations to come, and with it the usefulness if not the very possibility of the Laguna Dam now under construction as a part of the Yuma project of the U. S. Reclamation Service.

The gravity of the situation will be more apparent when we present information regarding the exact nature of the recent break. This information comes to us from engineers who have visited the scene of the disaster. They state that the latest break was primarily due to the passage of portions of a relatively low flood *beneath* the levee, a mile or so below the closure works. The water thus let loose had a free course back to the new river channel which had just been closed, merely flowing along the landward toe of the levee and through the borrow ditch left by constructing the levee. Eventually the levee at the initial break collapsed, and still later the current of water in the borrow ditch (so the account runs) ate into the back or landward side of the levee near the closure works, causing a collapse here, also. The break at this point soon widened and again diverted the main flow of the river into the Salton Basin.

The initial undermining of the levee is thus explained: The elevated banks of the Colorado are full of both horizontal and vertical cracks, the former due to stratification, the latter to shrinkage, and both increased by the decay of rank vegetable growths in rich, moist, hot soil. In the stress of the recent closure work little was done to safeguard the levee built on light, erodible soil, containing cracks as noted. One report that has reached us says the ground beneath the levee was plowed, and another says that it was not. We are informed that the embankment was built "dry." The borrow ditch close by the levee, while adding to the greatly-needed speed of construction, was an obvious source of weakness, once the tiniest stream of water found its way beneath or through the levee to the ditch. Sheet piling in connection with the levee was started by the engineer-in-charge, we are informed, but suspended "by order" in the desire to concentrate all efforts on the speediest possible closure.

As we pointed out in our issue of Dec. 27, 1906, the mere presence of a steeply-sloping new channel to the Salton Sea changes the whole aspect of overflows of the lower Colorado. Formerly such overflows were dissipated over large areas, or at best found only badly-silted channels, in either case encountering and being retarded by more or less of a tangle of vegetable growth. Now a large, deep and relatively steep channel greedily receives and hurries on the overflows, increasing them in the act. Thus has the hasty, thoughtless act of men changed the regimen of the Colorado, established through centuries of river-bed upbuilding!

We understand that the Southern Pacific, as we announced last week, is engaged in the seventh attempt to close the break. As already stated, the time available before the spring floods is very short, and another failure may render control impossible, short of the expenditure of millions upon millions. Without disparaging the heroic efforts of the engineers heretofore engaged in this unequal struggle, we feel it our duty to say that altogether too heavy a burden of responsibility has been thrust upon them. The higher officials of the Southern Pacific Co., in justice to their own engineers, to the local interests and to the national interests involved, should call skilled hydraulic engineers to the aid of their railroad engineers. It is one thing to throw temporary trestles or rock work across a railway break made by a Western river torrent, and quite another to confine to its channel a mighty river in flood, especially when the regimen of the stream has been overthrown in the manner described. In the new plan that must be evolved for the control of the Colorado the most expert engineering advice the country affords should be sought and followed.

The present typhoid epidemic at Scranton, Pa., appears to have originated in relatively minor contamination of a portion of the water supply of the city and to have gained headway before control measures were instituted, owing to gross negligence in reporting typhoid cases. Until investigations now in progress are completed it is perhaps best to say little about the initial responsibility for the outbreak, but the original and continued delinquency of the physicians in reporting cases cannot be condemned too early or too often. This delinquency has greatly delayed measures to control the outbreak, particularly secondary cases, and has of course been a serious handicap in attempts to ascertain the exact cause of the epidemic. The most obvious lessons of the Scranton epidemic, thus far, are: (1) the constant menace of unprotected and unfiltered surface water supplies and (2) the necessity of prosecuting physicians who fail to report typhoid cases promptly, as the law requires.

COLUMN FORMULAS IN RELATION TO THE PRACTICAL COLUMN.

There is no better device for "whipping the devil round the stump" than the invention or promotion of a new column formula. In times gone by it was a rather popular amusement; today it is out of fashion. Not that the utmost pitch of perfection has been attained; rather, a conviction of the fruitlessness of the diversion has impressed itself quite deeply into the current traditions of engineering. To-day our armament for column design is just about the same as that of a quarter century ago, and we are satisfied.

But column design presents a curious anomaly in the structural field. Progress in mechanics has constantly tended toward the more accurate analysis of force-actions on bodies and structures, leading to design on the basis of actual maximum stresses existing in the material. The aim is to compute the actual simple stress at the worst

point of a loaded member, and then, knowing the stress at which failure would begin under direct simple loading, to proportion the member so as to leave only a definite predetermined safety margin of stress. Now, in designing a column the procedure is radically different: the actual stresses in the member are not computed, and, in fact, we do not know how to compute them. The precise shape of the structure is not known to us, but only its approximate shape; and, since it happens that a column is so constituted that a small variation of form makes a large difference in the stress distribution, it follows that our approximate knowledge is far indeed from being close to the truth. Thus, we know that actual columns are never absolutely uniform in character, or of a form whose central axis is a straight line; and if in a chance case these conditions should be satisfied within vanishingly small limits, then it is not probable that the center of loading would coincide with the central axis. Yet in spite of these conditions we serenely go about designing compression members on the basis of the ideal, straight, centrally loaded column. It is certain that the unit loads which we thus apply cannot be a measure of the actual existing stresses.

The case is saved by various ingenious subterfuges of reasoning employed to modify the theoretical results of the ideal column, though these reasonings themselves profess to deal only with the ideal column. By their means we (in effect) use a series of varying safety factors in adapting material of known strength to given unit loads on columns. The results, it happens, harmonize fairly well with the showing of failure tests of columns as far as the limited range of experiment goes; and this is perhaps the most noteworthy feature of the whole matter. But whether the results be right or wrong, it remains a fact that in designing columns we do not proceed in the same way as in designing other structural parts. The procedure actually employed is best termed one of guess work; it is arbitrary and artificial in a degree found in no other phase of structural design.

Those who, in reverent contemplation of Rankine's formula and similar theoretical deductions, are not prepared to concede the preceding statement, may be better served by the reflections contained in the following four paragraphs:

1. Euler's formula accurately defines the relation of load and stability of an ideal "long column" centrally loaded. It informs us that such a column remains perfectly straight under all loads less than the critical; if deflected slightly from true straightness by a momentary lateral force, the column returns to straightness [this is readily shown by a study of the loaded "long column" considered as a vibrating reed]. When the critical load is imposed the column is in neutral equilibrium, and if deflected will not return to straightness [the vibration period of the vibrating reed under this load is computed to be infinite]. At all higher loads the column fails without delay. What interests us at present is not this failure, but the fact that the column remains perfectly straight under all loads less than the critical. This fact means that the unit stress in the material is given by the quotient of load divided by cross-section area.

2. At the other end of the scale from the "long column" there is the "short block." In this latter no buckling takes place. Over all load ranges, even at failure, the unit stress equals load divided by cross-sectional area.

3. Between the long column and the short block lie all the columns used in practice; let us call them "short columns." Some of these latter, experience shows, may fail by buckling, being similar to the long column in this, while others fail by direct crushing, like the short block; the former have a "critical load," the others merely an ultimate crushing load. It will be clear that the characteristics of short columns (still retaining the ideal conditions of symmetry and central loading) must lie between the characteristics at the two extremes of the scale. Therefore, applying to the short column our knowledge of the behavior of the long column and the short block, we must conclude that the column cannot deflect at loads short of the "critical" or failure point. Further, since the loads imposed in the practical use of columns are far below the critical point, the centrally loaded column in actual use always remains straight.

4. So long as the column remains straight [as just shown, this is the case throughout the range of practical loading], the longitudinal stress at any cross-section of the column is uniformly distributed over the section. The stress intensity therefore equals total load divided by area of cross-section. If the procedure of design of column were as rational as that of other elements of structural design, we should then proportion a column just like a short block—that is, divide the total load by the allowable unit compression of the material—to obtain the required cross-section area. What is actually done is that a reduced allowable stress is employed, found by multiplying the normally allowed compression by an arbitrary reduction factor. The arbitrary character of this reduction is not lessened by the fact that the reduction factor is computed by a "column formula." For these column formulas, while pretending to be based on purely central loading, claim to define the increased stress due to "column action"; yet, as we have shown, there is no such increased stress, and therefore no possible warrant for a reduction factor. The conclusion is inevitable that if the current theory is based only on the centrally loaded symmetrical column it is false, artificial and arbitrary, the same conclusion which was stated four paragraphs above.

That the results of an artificial procedure based on a false theory yet agree with experimental fact demonstrates conclusively that the premises on which the theory is based are erroneous. We start with certain assumptions as to the nature of the structure in question, develop a theory fatally inconsistent with fact, and arrive at substantially correct results. The conclusion must be that we were wrong in the premises, for there is no chance of compensating error in the theoretical deduction. The premises are: A homogeneous, symmetrical column, centrally loaded. These are ideal assumptions which we know a priori cannot hold true, and, as just shown, the results confirm their non-applicability [for, if they were true, columns should be proportioned as short blocks]. Yet in the face of this double showing of falsity, these same assumptions have continued in exclusive use from the earliest days of column analysis, and are still reverently employed.

The easy justification of this continued false practice is found in the statement that we do not know how far actual conditions depart from the ideal conditions, and that, moreover, since the amount of departure must be different for every different column, we can never know, and therefore can never obtain true assumptions on which to base a theory.

We believe, however, that a species of empirical study may be employed to establish foundations for a more rational theory. Such a theory should prove of value, because giving a clearer comprehension of column problems, even if the results of present-day practice (which, as already stated, agrees fairly well with experiment) be left unchanged, or even if they be actually made the basis of the new study. In the following we propose to develop a semi-empirical study of this character, basing it on the formulas and experiences of current practice, but of such a nature as to give this practice a rational background.

A meritorious effort in a parallel direction was made several years ago by Mr. J. M. Moncrieff, M. Am. Soc. C. E., of Newcastle-on-Tyne, England, in an elaborate paper presented before the American Society of Civil Engineers.* Mr. Moncrieff, beginning with a recognition of the fact that the distinctive feature of the practical column is eccentricity of loading, initial curvature, etc., in short, imperfection of manufacture (which may be represented in its results by an *equivalent eccentricity* of loading), proceeded to search in the records of experiments on column strength for a basis on which the equivalent eccentricity of columns might be estimated. The only tests he found available for this purpose were those of Eaton Hodgkinson, in 1840, on cast-iron columns, and of James Christie, in 1883, on wrought-iron struts. For his methods and results we must refer to Mr. Moncrieff's paper; suffice it to say that he develops rather complex formulas expressing the maximum stress in a column of given proportions under given load with given eccentricity, and he comes to the conclusion that the equivalent eccentricity probably varies directly as the dimensions of the cross-section, but is independent of the length.

The last-stated conclusion lacks plausibility, for it attributes to a heavy, stiff column a greater degree of imperfection than to a slender, less robust, column of the same length; and it charges a 20-ft. column of given section with the same eccentricity as one 40-ft. long. It is possible that columns like the small cast-iron test objects of Hodgkinson may follow this or a similar law of imperfection, but before accepting the law for the built steel columns of modern practice, or even for cast-iron or timber posts, we would require quite convincing evidence.

The weak point of Mr. Moncrieff's method lies in attempting to deduce values of equivalent eccentricity from the tangled and erratic records of column tests embracing columns of many kinds and from many sources. Equivalent eccentricity necessarily is a term which has meaning only when applied to averages (not to individual tests), and which is vitally dependent on the methods of producing the material manufacturing the columns. In fact, when Mr. Moncrieff concludes that the ratio of eccentricity to lateral dimension of column appears to be practically constant, he yet is forced to assign upper and lower limits to this ratio, the upper limit being no less than four times the lower. It would be difficult to make much practical application of values varying so greatly: values whose range sometimes corresponds to a difference in permissible unit load of as much as 5,000 lbs. per sq. in.

In studying the peculiarities of column formulas, on the basis of principles identical with those which form Mr. Moncrieff's point of beginning,* we discover a means for obtaining a measure of equivalent eccentricity which on comparison with the other seems to be rather more useful.

Any actual column differs from the centrally loaded "short column" in the following points: (a) Its geometrical axis is not absolutely straight; (b) its material is not distributed with absolute symmetry around the geometrical axis, in other words the gravity axis does not coincide with the geometrical axis; (c) the line of pressure does not absolutely coincide with the gravity axis. Concerning these differences, we note as proof the fact that they represent unavoidable divergences from the assumptions which define the "ideal column." In other points actual columns are substantially like their abstract prototype; their material is fairly homogeneous and has a uniform modulus of elasticity, and its elastic behavior may be expressed by Hooke's law. These points of similarity will be utilized in the analysis, inasmuch as they permit us to apply the "common theory of flexure." The points of difference require special notice.

THE ECCENTRICALLY-LOADED COLUMN.—The three distinctive features of the practical column—departure from straightness, departure from symmetry, and eccentricity of loading—all have a common effect. They act to subject each cross-section of the column to a bending moment, in addition to the centric compression. The super-position of the bending stress and the direct stress produces increased compression along the side nearest the load. We may measure all three characteristics in terms of one of them, the simplest, namely, eccentricity of loading.

Let us, then, consider a straight column, of length L, constant cross-section area A, and loaded with a load of P pounds acting in a line

*Transactions, Am. Soc. C. E., XLV. (1901) pp. 334-431.

*"The underlying principles upon which the reasoning is based are, (1) that a perfectly centered column of perfect material and straightness is an ideal conception seldom or never realized in practice, and (2) that the various disturbing influences preventing the realization are practically all capable, as regards their ultimate effect, of being represented by an equivalent eccentricity of loading."—Moncrieff, Trans. Am. Soc. C. E., XLV., 335.

parallel to the axis of the column, but at distance e from the axis (i e., eccentricity = e). If this column were absolutely rigid, suffering no lateral deflection under this load, the stresses would be as follows:

(1) At each section a uniformly distributed compression,

$$s_1 = P/A,$$

and (2) at each section a bending moment M = Pe, producing an extreme fiber stress, as given by the beam formula s = Mc/I,

$$s_2 = Pec/I = Pec/Ar^2 = (P/A)\ (ec/r^2),$$

where I is the moment of intertia of the cross-section, r the radius of gyration, and c the distance from neutral axis of section to extreme fiber.

On the side nearest the line of action of the load the two partial stresses would be additive, both being compression, producing a maximum combined stress

$$s = s_1 + s_2 = (P/A)\ (1 + ec/r^2) \quad \ldots\ldots\ldots (1)$$

THE RANKINE FORMULA AND THE ECCENTRIC COLUMN.—Formula (1) expresses the maximum compressive stress in the rigid column in terms of the unit load p = P/A. It will be recognized that this unit load p is the quantity which is ordinarily fixed by "column formulas." For instance, if the designer uses a formula of the Rankine type,

$$p = \frac{S}{1 + \frac{1}{B}\left(\frac{L}{r}\right)^2} \quad \ldots\ldots\ldots (2)$$

he takes the following steps: First, he selects an allowable compressive stress S, say 16,000 lbs. per sq. in., for structural steel. Knowing the length of the column required and guessing at a probably correct value of r, the radius of gyration of the column section, he computes the value of p (the value of B is given by the maker of the column formula). Then he divides the load to be carried, P, by this value of p to find the required area of cross-section, i. e., A = P/p, which means that, in the finished column, p = P/A.

Comparing this procedure with the foregoing analysis of an eccentrically loaded column, we observe, first, that P/A is identical in the two formulas; second, that the allowable compression S seeks to fix the same quantity as is defined by s, the extreme fiber compression, in the other formula. We may therefore equate the maximum stress s to the allowable stress S. By transforming the Rankine formula (2) we get

$$S = p\left(1 + \frac{1}{B}\frac{L^2}{r^2}\right)$$

which we now equate with Eq. (1), obtaining

$$(P/A)\ (1 + ec/r^2) = p\left(1 + \frac{1}{B}\frac{L^2}{r^2}\right)$$

Noting that p = P/A, we find

$$ec/r^2 = L^2/Br^2,$$

or

$$e = L^2/cB = 2L^2/bB \quad \ldots\ldots\ldots (3)$$

where b denotes the width of the column, equal to twice c.

This means that the Rankine formula (2), generally supposed to apply to centrally loaded columns, may be interpreted as a formula for the ratio between average compression and maximum compression in an eccentrically loaded column having an eccentricity whose amount is defined by Eq. (3). Now, if we premise that the Rankine formula gives results which agree well with actual experience in the strength of columns, then we are forced to conclude that these columns have an average imperfection or eccentricity expressed by Eq. (3), e = 2L²/bB, where

e is the eccentricity of loading;

L is the length of the column;

b is the least width of the column (twice the least distance from neutral axis to extreme fiber);

and B is the reduction constant in the Rankine formula.

To take a concrete case, look at the much-used formula

$$p = \frac{16{,}000}{1 + \frac{L^2}{24{,}000\ r^2}},$$

which is of the Rankine type. Here the value of B is 24,000. If this formula be applied to a column 20 ft. long (L) and 10 ins. in least width (b), we find by Eq. (3) that the probable eccentricity of loading, or imperfection in manufacture is

$$e = 2L^2/bB = \frac{2 \times 240 \times 240}{10 \times 24{,}000} = 0.48 \text{ in.}$$

a result which assumes, of course, that in actual experience columns have just the strength imputed to them by the Rankine formula with a value of 24,000 for B. Similarly, if the strength of columns is more correctly expressed by the Rankine formula with B = 12,000, thus,

$$P/A = \frac{S}{1 + \frac{L^2}{12{,}000\ r^2}},$$

then the mean eccentricity of a column 20 ft. long and 10 ins. wide is

$$e = \frac{2 \times 240 \times 240}{10 \times 12{,}000} = 0.96 \text{ in.}$$

We have elaborated the above calculations in order to show that the Rankine column formula may be viewed as a correct formula for eccentrically loaded columns, instead of, as commonly interpreted, a formula based on central loading. Further, that if the Rankine formula correctly defines the strength of columns as actually built, then these columns are on the average affected by eccentricity to an amount defined by Eq. (3).

An examination of this equation shows that the eccentricity varies as the square of the length, and inversely as the diameter of the column. Expressed otherwise, it means that a column 30 ft. long is likely to have four times as great a departure from true straightness as a column 15 ft. long, and that a column 16 ins. wide will on the average be only half as crooked, or have only half as great eccentricity of loading, as a column 8 ins. wide. Or we can write the equation thus:

$$e = K\frac{L}{b}L,$$

where K is constant, equal to 2/B. Now, in this form the equation means that for columns of similar proportions—that is, for the same value of L/b—the eccentricity varies directly as the length. Two similar columns, one of which is four times as large as the other in every dimension, will have eccentricities proportional to their dimensions; the larger column will have an eccentricity four times as great as the column of only one-fourth its size.

These conditions of proportionality appeal to the mind as reasonable, and agree well with all the practical factors in column production. We are not yet prepared to scrutinize them fully, however, because of the error committed in assuming that the column is perfectly rigid, or, what amounts to the same thing, neglecting the deflection caused by the load, as compared with the initial eccentricity.

THE INFLUENCE OF DEFLECTION.—Taking the column previously considered, let us carefully study its deflection under load. Calling its initial eccentricity of loading e_o, the load will cause the column to bend away from the line of loading by an amount Y, so that the final eccentricity at mid-length becomes $e_o + Y$; at the ends, however, the deflection is zero and the eccentricity remains e_o. Now, the maximum stress occurs where the bending moment is greatest—that is, at the center—and here

$$s_2 = \frac{M\ c}{I} = \frac{P\ (e_o + Y)\ c}{I},$$

and the total maximum compression at this point is

$$s = (P/A)\ [1 + c\ (e_o + Y)/r^2] \quad \ldots\ldots\ldots (4)$$

By comparing this equation with Eq. (1), we see that, for equal maximum stress, $e = e_o + Y$; and, in fact, by directly comparing (4) with the Rankine formula (2), as before, we find

$$e_o + Y = 2L^2/bB \quad \ldots\ldots\ldots (5)$$

It will be seen that this is the same as Eq. (3), previously found, giving the value of e for a rigid column. In other words, the flexible column is stressed to the same degree as if it were absolutely rigid and were affected by an initial eccentricity of loading whose amount is defined by Eq. (3).

The true initial eccentricity e_o, which measures the imperfection of the column, is less than the value of e, however, and it may be of service to find the actual amount of this *initial* eccentricity. By calculation of the curve of deflection, we readily find that

$$Y = e_o\left(\sec\sqrt{\frac{PL^2}{4EI}} - 1\right) = k_1 e_o \quad *$$

and

$$e_o = (e_o + Y)\cos\sqrt{\frac{PL^2}{4EI}} = k_2\ (e_o + Y) = k_2 e \quad *$$

The values of the two factors k_1 and k_2 have been computed for the safe loads allowed by three column formulas, two of the Rankine type and one of straight-line form; and for columns of three different values of L/r, namely, 60, 100 and 150; they are given in the following tabulation:

DEFLECTION FACTORS FOR COLUMNS UNDER WORKING LOAD.

Load computed by Column Formula given at left.

Formula.	L/r	$k_1 = Y/e_o$	$k_2 = e_o/e$ By exact formula.	$k_2 = e_o/e$ By Moncrieff's approximation.
$P = \frac{16{,}000}{1 + \frac{L^2}{24{,}000\ r^2}}$	60	.262	.792	.798
	100	.795	.557	.562
	150	2.271	.307	.314
$P = \frac{15{,}000}{1 + \frac{L^2}{13{,}500\ r^2}}$	60	.215	.823	.828
	100	.533	.652	.660
	150	.982	.505	.515
$P = 20{,}000 - 90\frac{L}{r}$	60	.278	.783	.788
	100	.774	.564	.573
	150	1.296	.435	.446

Relative to the high value of k_1 given by the first formula for L/r = 150, it should be said that this particular formula gives such a small "column reduction" that it should not be used for columns as slender as L/r = 150. In fact, for this ratio it permits a unit stress of 8,250 lbs., whereas the Euler limit is only 12,720 lbs. per sq. in. That is to say, if this column were truly central in make-up and loading, it would still have a safety factor of only 1½ against buckling. Or, from another viewpoint, under slightly eccentric loading it has a deflection 2¼ times as great and a final eccentricity 3¼ times as great as the initial eccentricity, an almost dangerously unstable condition.

The other cases represented in the table are more normal. The values of k_2 given for them show that the final eccentricity is never greater than about twice the initial eccentricity, and generally is only 1⅓ to 1½ times the initial eccentricity. In other words, following again our previous argument, the actual eccentricity or imperfection of manufacture is 65% to 75% of the amount given by Eq. (3).

We might go farther in our calculations and show, for instance, that if the column is not straight initially, but has a slight curvature in the same direction as the eccentricity of loading, then the deflection under load is less than with a straight column of the same *mid-length* eccentricity; and that in this case the ratio of initial to final eccentricity lies between the ratio of 0.65 to 0.75 (of the straight flexible column) and the ratio 1.0 (of the straight rigid column). But such elaboration is not necessary for the purposes of the present article.

Indeed, since the above-found ratios of 0.65 to 0.75, or even 0.50, are not inordinately small, we

*A notable simplification of this calculation is proposed by Mr. Moncrieff in the paper already cited. By assuming the curve of the deflected column to be a parabola, the trigonometric terms are eliminated, and

$$Y = e_o\frac{P\ L^2}{8\ E\ I - \frac{5}{6}\ P\ L^2}$$

and

$$e_o = (e_o + Y)\frac{8\ E\ I - \frac{5}{6}\ P\ L^2}{8\ E\ I + \frac{1}{6}\ P\ L^2}$$

so that the constants in the text above, k_1 and k_2, are

$$k_1 = \frac{P\ L^2}{8\ E\ I - \frac{5}{6}\ P\ L^2} = \frac{p\ L^2/r^2}{8\ E - \frac{5}{6}\ p\ L^2/r^2}$$

$$k_2 = \frac{8\ E\ I - \frac{5}{6}\ P\ L^2}{8\ E\ I + \frac{1}{6}\ P\ L^2} = \frac{8\ E - \frac{5}{6}\ p\ L^2/r^2}{8\ E + \frac{1}{6}\ p\ L^2/r^2}$$

The latter formula has been computed for certain values of P, L and r and the results given for comparison with those of the exact formula in the table in the text. The agreement is remarkably close.

may for the present purpose disregard all difference between initial and final eccentricity. By taking the computed value of final eccentricity to represent the initial eccentricity, we commit a small error which is on the side of safety, and at the same time secure a great simplification of the formula. In a subject of so much approximation as that of column strength an error of this kind is not momentous. We will therefore accept Eq. (3) as giving a measure of the eccentricity or imperfection of practical columns, when the Rankine type of formula is assumed as a true representation of column strength.

THE STRAIGHT-LINE FORMULA AND THE ECCENTRIC COLUMN.—The stresses in an eccentrically loaded column may be compared with a formula of the popular straight-line type in the same way as with the Rankine.

The straight-line formula,

$$p = S - C\frac{L}{r}, \quad \ldots\ldots\ldots\ldots\ldots\ldots (6)$$

may be written thus:

$$S = p\left(1 + \frac{C}{p}\frac{L}{r}\right)$$

or approximately

$$S = p\left(1 + \frac{C}{p'}\frac{L}{r}\right)$$

if p' be put for a mean value of p, say the value for L = 70 r.

Comparing this with Eq. (1), which defines the maximum stress in an eccentrically loaded rigid column, we obtain

$$\frac{e\,c}{r^2} = \frac{C}{p'}\frac{L}{r}$$

or

$$e = \frac{C}{p'}\frac{L r}{c} = 2\frac{C}{p'}\frac{L r}{b} \quad \ldots\ldots\ldots\ldots (7)$$

In a given shape of column cross-section the ratio r/b is constant throughout all variations of length and horizontal dimensions. By using a fixed value for this ratio, we simplify Eq. (7). The precise value used is of little importance at present, and we may take as extreme values r = 0.25b for a solid round section, and r = 0.40b for a heavy box section. Applying these values gives

$$e = 0.5\frac{C}{p'} - L \quad \ldots\ldots\ldots\ldots\ldots (8a)$$

and

$$e = 0.8\frac{C}{p'} - L \quad \ldots\ldots\ldots\ldots\ldots (8b)$$

for the two sections in question.

Interpreted as before, these equations mean that, if the strength of solid round columns is correctly expressed by the straight-line formula (6), then Eq. (8a) defines the probable eccentricity, or imperfection of manufacture; and if formula (6) applies correctly to columns of heavy box section, then these columns have probable eccentricities defined by Eq. (8b). In either case

FORMULAS OF RANKINE TYPE.

$$p = \frac{S}{1 + \frac{L^2}{Br^2}}$$

$$e = \frac{2\,L^2}{b\,B}$$

I.—STEEL.

Authority.		Formula.		Equivalent Eccentricity. e
Phoenix, 1895 Osborn, 1903 Godfrey, 1906...	Square end.....	$p = \frac{S}{1 + L^2/36000\,r^2}$	.....	0.000055 L^2/b
	Square and pin....	$p = \frac{S}{1 + L^2/24000\,r^2}$	.....	0.000083 L^2/b
	Pin ends.....	$p = \frac{S}{1 + L^2/18000\,r^2}$	.....	0.000111 L^2/b
Cambria, 1901....	.....	$p = \frac{S}{1 + L^2/36000\,r^2}$	.....	0.000055 L^2/b
American 1900 Bridge Co.....	Soft steel.....	$p = \frac{S}{1 + L^2/13500\,r^2}$	.....	0.000148 L^2/b
	Medium steel.....	$p = \frac{S}{1 + L^2/11000\,r^2}$	.....	0.000182 L^2/b
4 Railroads †† 1898-1902.....	.....	$p = \frac{S}{1 + L^2/20000\,r^2}$	.....	0.000100 L^2/b
9 Railroads †† 1899-1902.....	.....	$p = \frac{S}{1 + L^2/18000\,r^2}$	.....	0.000111 L^2/b
1 Railroad †.....	.....	$p = \frac{S}{1 + L^2/15000\,r^2}$	.....	0.000133 L^2/b
1 Railroad †† 1896.....	.....	$p = \frac{S}{1 + L^2/14000\,r^2}$	.....	0.000143 L^2/b
1 Railroad †† 1899.....	.....	$p = \frac{S}{1 + L^2/13500\,r^2}$	.....	0.000148 L^2/b
Merriman "Rational" Eng. News July 19, 1894....	.....	$p = \frac{S}{1 + \frac{n\,S}{\pi^2 E}\frac{L^2}{r^2}}$	n 1/4 Fixed ends..... 4/9 Fixed and pin.... 1.0 Pin ends..... Mean Eccentricity,	§0.000025 L^2/b 0.000044 L^2/b 0.000100 L^2/b 0.000103 L^2/b

II.—CAST-IRON.

Chicago Building Dept. (Kent).....	Round column....	$p = \frac{S}{1 + L^2/600\,b^2}$	.....	††† 0.000333 L^2/b
	Square column....	$p = \frac{S}{1 + L^2/800\,b^2}$	.....	‡‡‡ 0.000313 L^2/b
Boston Building Dept. (Kent).....	Round column....	$p = \frac{S}{1 + L^2/800\,b^2}$	.....	††† 0.000250 L^2/b
	Square column....	$p = \frac{S}{1 + L^2/1067\,b^2}$	.....	‡‡‡ 0.000234 L^2/b
Former New York Bldg. Dept.(Kent)	Round column....	$p = \frac{S}{1 + L^2/400\,b^2}$	.....	††† 0.000500 L^2/b
	Square column....	$p = \frac{S}{1 + L^2/500\,b^2}$	.....	‡‡‡ 0.000500 L^2/b

III.—TIMBER.

Passaic, 1903.....	.....	$p = \frac{S}{1 + L^2/1100\,b^2}$	.....	0.000151 L^2/b
Osborn.....	Highway Br.....	$p = \frac{S}{1 + L^2/1000\,b^2}$	.....	0.000167 L^2/b
C. S. Smith (in Trautwine, p. 963).....	White or Y. Pine..	$p = \frac{S}{1 + L^2/250\,b^2}$	.....	0.000667 L^2/b

FORMULAS OF MISCELLANEOUS TYPE.

U. S. Forestry Bureau (A. L. Johnson)..	.....	$p = S\frac{700 + 15\,L/b}{700 + 15\,L/b + L^2/b^2}$	$e = \frac{1}{4200 + 90\,L/b}\frac{L^2}{b}$	= §§ 0.000167 L^2/b
Waddell, De †††† Pontibus.....	Hard wood.....	$p = 1700 - 0.4\,L^2/b^2$	.....	0.000043 L^2/b
	Soft wood.....	$p = 1000 - 0.2\,L^2/b^2$	.....	0.000036 L^2/b

FORMULAS OF STRAIGHT-LINE TYPE.

$$p = S - C\frac{L}{r}$$

$$e = 2\frac{r}{b}\frac{C}{p'}L$$

p' = p for L = 70 r

I.—STEEL.*

Authority.	Material.	Formula.	Equivalent Eccentricity e
Waddell De Pontibus 1903	Top chords	p = 18000 − 70 L/r	0.0043 L
	End posts	p = 18000 − 80 L/r	.0052 L
	Other fixed end struts	p = 18000 − 60 L/r	.0041 L
	Other hinged end struts	p = 18000 − 80 L/r	.0062 L
Cooper 1906 R. R. Bridges	Chords	p = 20000 − 90 L/r	.0053 L
	Posts, through bridges	p = 17000 − 90 L/r	.0067 L
	Posts, deck bridges	p = 18000 − 80 L/r	.0052 L
	Laterals	p = 13000 − 60 L/r	.0055 L
Carnegie † 1897	.....	p = 17100 − 57 L/r	.0035 L
Passaic ‡ 1903	Med. Steel	p = 15000 − 57 L/r	.0041 L
	Soft steel	p = 13500 − 50 L/r	.0040 L
Buel 1906	.....	p = 16000 − 67 L/r	.0047 L
R R. †† 1902	Soft steel	p = 16000 − 75 L/r	.0058 L
	Med. steel	p = 18000 − 90 L/r	.0062 L
R. R. ††	Soft steel	p = 10000 − 50 L/r	.0062 L
	Med. steel	p = 16000 − 80 L/r	.0062 L
R. R. †† 1898	Soft steel	p = 9000 − 35 L/r	.0043 L
	Med. steel	p = 10000 − 41 L/r	.0046 L
R. R. †† 1902	.....	p = 8000 − 45 L/r	.0074 L
R. R. †† 1899	Soft Steel	p = 7000 − 37 L/r	.0067 L
	Med. steel	p = 8500 − 45 L/r	.0067 L
P. & R. Ry. 1901	Angle Struts	p = 9000 − 30 to 34 L/r	.0035 to .0041
New York Bldg. Code	Steel	p = 15200 − 58 L/r	.0042 L
	Wrt. Iron	p = 14000 − 80 L/r	.0076 L
		Mean Eccentricity,	.0053 L

II.—CAST IRON.

Godfrey 1906	.....	p = 7600 − 40 L/b	††† .0012 L
Burr (Quoted by Kent, p. 251)	.....	p = 30500 − 160 L/b	††† .0012 L
New York Bldg. Code	.....	p = 11300 − 30 L/r	††† .0021 L

III.—TIMBER.

B. & O. R. R., 1901. (Quoted in Trautwine, 1906, p. 768.)	Yellow pine	p = 1200 − 18 L/b	.0036 L
	White pine	p = 800 − 12 L/b	.0036 L
	White oak	p = 1000 − 15 L/b	.0036 L
Godfrey, 1906	Oak	p = 1000 − 18 L/b	.0047 L
	White pine	p = 800 − 15 L/b	.0050 L
New York Bldg. Code	W. P., N. P. spruce	p = 800 − 15 L/b	.0050 L
	L. I. Y. pine	p = 1000 − 18 L/b	.0047 L
	Oak	p = 900 − 17 L/b	.0051 L

* Values of e computed for ratio r/b = 0.8 or r/b = 0.4, as in box section.

† Above L/r = 90; below this limit 12000 lbs.

‡ Above L/r = 50 for Medium and 30 for Soft steel; below these limits use 12000 lbs.

†† Formulas used by various railways; from table in "A Comparison of the Requirements of Recent Railway Bridge Specifications," by Prof. A. H. Heller, Eng. News, November 19, 1903, p. 444.

††† Assuming $b^2 = 10r^2$ (for round, hollow section).

‖ For solid rectangular section $b^2 = 12r^2$.

§ Assuming S in denominator = 15000. π^2 = 10, E = 30,000,000.

‡‡‡ Assuming $b^2 = 8r^2$ (for square hollow section).

†††† With same approximation as used in deriving eccentricity of straight-line formula, this gives an eccentricity of same form as that of Rankine type. Coefficients computed with p' at L = 70 r substituted for p in denominator.

§§ Calculating coefficient for L = 70 r.

the equivalent eccentricity of the straight-line formula varies directly as the length of the column, and is independent of the dimensions of the cross-section.

The remarks previously made relative to the deflection under load apply to the straight line formula equally as much as to the Rankine formula. The factor $k_2 = e_o/e$ is computed in the same way, and was so computed for the third series of the table given above. As there shown, we may reasonably assume that the substitution of final for initial eccentricity is permissible for the present purpose.

Using the formulas for eccentricity above derived [Eq. (6), (8a) and (8b)], we have gathered together a list of column formulas recommended by various American bridge and structural authorities of recent date, and have computed the equivalent eccentricity implied by each. The results are given in the subjoined table, where the authority recommending the formula is also stated. Most of the formulas in the table are for steel columns, but a few formulas for cast-iron and timber columns are included to give a comparison with practice in steel columns in point of eccentricity. One or two column formulas of special type are also cited, and their eccentricities given as computed by the methods used above. Finally, the values of eccentricity estimated by Mr. J. M. Moncrieff for six cast-iron columns tested by Hodgkinson and six wrought-iron struts tested by Christie are given, and also the coefficients of L and of L^2/b to which these values correspond; these coefficients may be compared with those computed for the several straight-line and Rankine formulas, respectively.

TWELVE TESTS OF CAST-IRON AND WROUGHT-IRON COLUMNS.

Equivalent Eccentricities Estimated by J. M. Moncrieff, on Basis of Observed Deflections.

I.—WROUGHT-IRON. **

(Round-ended Columns, Tests by J. Christie.)

1.—1x1-in. Tee, 98.25 in. eff. length.
Estimated $\epsilon = 0.05$, $V = 0.025$; $\therefore e = \epsilon + V = 0.075$ ins. $= .0008$ L .000008 L^2/b

2.—3x3-in. Tee, 80.06 ins. eff. length.
Estimated $\epsilon = 0.02$, $V = 0.035$; $\therefore e = \epsilon + V = 0.055$ in. $= .0007$ L .000026 L^2/b

3.—2½x2½-in. Tee, 80.37 ins. eff. length.
Estimated $\epsilon = 0.035$, $V = 0.05$; $\therefore e = \epsilon + V = 0.085$ in. $= .0011$ L .000033 L^2/b

4.—1½x1½-in. Tee, 80.19 ins. eff. length.
Estimated $\epsilon = 0.05$, $V = 0.03$; $\therefore e = \epsilon + V = 0.08$ in. $= .0010$ L .000019 L^2/b

5.—2x2-in. Tee, 62.19 ins. eff. length.
Estimated $\epsilon = 0.10$, $V = 0.02$; $\therefore e = \epsilon + V = 0.12$ in. $= .0019$ L .000062 L^2/b

6.—1x1-in. Tee, 44.25 ins. eff. length.
Estimated $\epsilon = 0.037$, $V = 0.008$; $\therefore e = \epsilon + V = 0.045$ ins. $= .0010$ L .000023 L^2/b

II.—CAST-IRON. ***

(Round-ended Columns, Tests by E. Hodgkinson.)

7.—Solid cylinder, 0.99-in. diam., 59.5 ins. eff. length.
Estimated $\epsilon = 0.055$, $V = 0.07$; $\therefore e = \epsilon + V = 0.125$ in. $= .0021$ L .000035 L^2/b

8.—Solid cylinder, 1.97 ins. diam., 58.5 ins. eff. length.
Estimated $\epsilon = 0.0675$, $V = 0$; $\therefore e = \epsilon + V = 0.0675$ in. $= .0012$ L .000039 L^2/b

9.—Hollow cylinder, 1.78 ins. O. D., 1.21 ins. I. D., 89 ins. eff. length. Core 0.19 in. out of center, solid section 0.163 in. out of center.
Estimated $\epsilon = 0.1$, $V = -0.02$; $\therefore e = \epsilon + V = 0.08$ in. $= .0009$ L .000018 L^2/b

10.—Hollow cylinder, 2.23 ins. O. D., 1.53 ins. I. D., 88.52 ins. eff. length. Core 0.135 ins. out of center, solid section 0.12 in. out of center.
Estimated $\epsilon = 0.175$, $V = -0.025$; $\therefore e = \epsilon + V = 0.150$ in. $= .0017$ L .000043 L^2/b

11.—Hollow cylinder, 3.36 ins. O. D., 2.61 ins. I. D., 87.39 ins. eff. length. Core 0.067 in. out of center, solid section 0.105 in. out of center.
Estimated $\epsilon = 0.16$, $V = 0.035$; $\therefore e = \epsilon + V = 0.195$ in. $= .0022$ L .000085 L^2/b

12.—Solid rectangular section, 1.54 × 1.66 ins., 59 ins. eff. length.
Estimated $\epsilon = 0.06$, $V = -0.015$; $\therefore e = \epsilon + V = 0.045$ in. $= .0008$ L .000020 L^2/b

NOTE.—V in the above list represents the initial curvature, and is the middle ordinate of the gravity axis of the unloaded column, measured from its chord; and ϵ is the eccentricity of the load line with relation to the end of the column axis. Thus $e = \epsilon + V$ is the distance between the column axis at midlength and the load-line.

** In making his trial calculation of deflection at various loads, to arrive by repeated trial, at a value of e, which would give deflections equal to the observed deflections, Mr. Moncrieff estimated the value of E, the modulus of elasticity of these wrought-iron struts, at figures varying from 18,500,000 lbs. (for col. No. 6) to 32,000,000 lbs. (for col. No. 3). If the same value of E had been assumed for all six struts, the "equivalent eccentricities" would compare quite differently.

*** The assumed values of E (Moncrieff) vary from 12,000,000 lbs. (col. No. 11) to 17,500,000 lbs. (col. No. 9).

The two types of formula under the heading Miscellaneous are anomalous. The Waddell parabolic formulas for timber posts involve a slight approximation in transformation, the same as did the straight-line formulas. The resulting equivalent eccentricity is of the same form as that of the Rankine formula, but numerically it is much lower than that given by the other timber column formulas, and even much lower than the average eccentricity for steel columns. The presumption, therefore, is against the constants of the Waddell formula. The complex U. S. Forestry Bureau formula, on the other hand, does not yield a simple expression for equivalent eccentricity, but one which resembles that of the Rankine formula, with a *variable* coefficient. The effect of this coefficient is to give a relatively smaller eccentricity for slender columns. The complex form of the expression for e, as well as the form of the column formula itself, puts the formula on the defensive, especially as, when plotted to coordinates of p and L/r, it differs very little from a properly chosen Rankine formula. Evaluated for L = 70 r, the same mean value employed in transforming the straight-line and the Waddell parabolic formulas, it gives a coefficient agreeing excellently with the others.

It is interesting to note that the coefficients deduced from Moncrieff's estimated eccentricities are far below the coefficients derived from formulas. The great irregularity of the former is to be expected, since they involve all the variation of single tests against the uniformity of a general law. Their low value is more difficult to account for, though. Whatever explanation may be assigned to it, the results of the comparison with the accepted values of present practice as represented by the column formulas cited do not show that the analysis of single tests is a promising method for studying the mean eccentricities occurring in practical construction.

The terms which appear in the formulas for equivalent eccentricity, corresponding to different column formulas, are of considerable interest. As has already been shown, the Rankine type of formula corresponds to an eccentricity which varies directly as the square of the length and inversely as the horizontal dimensions of the column, or, expressed otherwise, it varies as the product of length multiplied by ratio of length to horizontal dimensions. The equivalent eccentricity of the straight-line formula, on the contrary, takes no account of the horizontal dimensions, but only of the length; it gives the same eccentricity for a box column 20 ft. long, whether it be made of 6-in. or of 10-in. channels. Be it remembered, however, that these eccentricities are expressed in linear measure, not in fractions of the width, and that the increased bending stress which a given eccentricity produces in a 6-in. column, as compared with a 10-in. column, is properly accounted for in the straight-line column formula.

It is difficult, without broad consideration and discussion, to pass judgment on the two formulas for equivalent eccentricity and decide whether that derived from the Rankine formula or that derived from the straight-line formula is preferable. A fair argument may be made for either. The fact that test records of steel columns, when plotted with unit load as ordinate on values of L/r, give curves having the general form of the plot of the Rankine formula, speaks in favor of considering the eccentricity to vary as L^2/b. But manufacturing practice and the peculiarities of the material are of vital bearing on the question. Thus, while one type of formula may be more reasonable for structural steel columns, the other may be more appropriate for wooden or cast-iron columns. A general exchange of opinion of engineers on the matter could not fail to be interesting.

It must not be forgotten, however, that this question is of no direct bearing on normal designing of columns. It has consistently been premised in the preceding that our present-day column formulas are satisfactory, being generally recognized to produce safe and economical columns. It is not the intention here to suggest any abandonment of these formulas, or to propose a substitute for them. Our analysis has the purpose only of showing how a rational column theory may be grounded.

Moreover, column design must take account of a second vital matter besides eccentricity, namely, the safety factor against lateral loads or shocks, vibration, and the like. It would be a serious mistake to assume that these incidental factors are cared for in the ordinary column formulas, or that they should or might be included with the effect of eccentricity in a single formula. For these factors are not inherent in the column, nor do they affect equally two similar columns located in different surroundings. They are fortuitous external circumstances, which are peculiar to the individual case, and therefore are subject to separate estimate and allowance in each instance. The allowance may be made by incorporating a greater safety factor in the allowed fiber stress S, or by calculating the stresses due to the probable secondary forces. The column formula itself is restricted to accounting for the behavior of the practical column under a definite and purely vertical, static loading. The distinction between column formula and provision against secondary actions, we regret to observe, is not always clearly appreciated.

While the actual designing of columns is not directly touched by the present study, there are, nevertheless, one or two distinct and immediate uses for the results presented. Thus, the proposal is made, now and then, to proportion columns by a flat unit stress, provided they have ample margin, in horizontal dimensions, against buckling. Let us analyze this plan by our method. The flat-rate stress may be expressed thus:

$$p = S - K,$$

or

$$S = p\,(1 + k),$$

and this can be compared with the stress equation (1). We have, then,

$$ec/r^2 = k,$$

or

$$e = \frac{k\,r^2}{c} = k'\,r.$$

The flat unit stress, in other words, implies an eccentricity independent of length of column and increasing directly with the horizontal dimensions; that is, a thicker and stiffer column is to

be charged with a greater eccentricity than a thinner, more flexible column. Such an implication appears to us wholly unreasonable, sufficiently so to condemn the flat-rate proposal offhand.*

Again, the designer is often called upon to deal with the case of a column having a definite bending moment in addition to the vertical load. How is this case to be treated? Under current methods of practice a problem of this sort always introduces perplexity. The designer may compute the average compression and the extreme fiber bending stress due to the moment and divide the allowable girder compression by this sum to obtain the required section modulus. Or he may compute areas separately for the vertical load (by column formula) and for external bending moment (by flexure formula), and add the two areas. The two methods give different results. On the basis of the theory here presented he is justified in following a third procedure, thus: Assume a specific eccentricity of load, given (say) by formula (3), and add its moment to the external bending moment to find total moment. If the moment is large, this total moment is to be used as the basis for a calculation of deflection, in order to obtain the final applied bending moment. Then, with an assumed radius of gyration of column section, and knowing the safe compressive stress of the material employed, the area required for the bending is obtained. Also, the quotient of vertical load divided by allowable unit stress gives the areas required for the direct stress. The sum of these two partial areas gives the total required cross-sectional area, which, with the assumed radius of gyration, gives a column of rational design to meet the conditions imposed.

A further use for the theory is found in designing compression members or columns in a material for which no generally accepted column formula exists. In such a case it will be necessary that the designer, from his knowledge of the nature of the new material and the methods of its production and fabrication, form an estimate of the probable eccentricity to be assumed for his finished column. The values deduced from practice in steel column design, for example, may be taken as a basis of comparison, and may according to the judgment of the designer be increased or decreased to give the eccentricity applicable to his new material. From this point on the design may proceed as a problem in eccentric column loading, or, by reversing the process used above, the designer may deduce a column formula for general use with the material in question.

Finally, if the view proposed in this discussion should have no other merit, it can at least be of service in turning attention away from the "ideal column" as a basis for the analysis of column strength, and checking many a fruitless effort to improve the theory of columns in the old direction. Such efforts should no longer find stimulus in the claim that the study of eccentric loading is resultless, because no knowledge as to actual eccentricities of supposedly central loading is available. For, as we have shown, a way is open to obtain at least a preliminary estimate of eccentricity, sufficiently definite to afford a safe instrument of calculation in column problems.

LETTERS TO THE EDITOR.

A Formula for the Crown of Paved Streets.

Sir: I submit for criticism a formula for determining the crown of paved streets:

C = amount in hundredths of a foot.
W = width between curbs in feet.
g = coef. for varying street grades, and decreases as street grade increases.
C = [(W − 5) 2] × 4 × g.
Where g = (100 − 5 × St. grade) 100.

The formula is derived from the relation of quantities involved, independent of all arbitrary numbers.

Respectfully,

J. Edgar Borden.
Engineering Dept., City of Fall River.
176 Winter St., Fall River, Mass., Dec. 14, 1906.

A Method for Vertical Curves at Grade Intersections.

Sir: In your issue of Nov. 22, page 548, Mr. H. G. Cowling asks information as to the best method for vertical curves.

The rule I use is the following: Take the difference in rates of the two grades and divide by one more than the length in stations of vertical curve to be put in. This will give the change in rate of grade from one station to the next on the curve. For instance, having a + 0.3% grade meeting a − 0.2%, the difference in rate is 0.5% and if we wish a vertical curve four stations long, divide 0.5 by 5 giving 0.1% as the change in rate. Then starting in two stations back from the apex with a known elevation, the rate of grade to the following station is + 0.3 − 0.1 = + 0.2%. The rate of grade to the next station is + 0.1% and so on around.

A length of curve is taken such that the difference in rate of grade between the stations is not more than 0.10% or 0.12%. Grade elevations are put on the profile at each station on the curve, but it is not necessary to put on the rate of grade. There is no need for a vertical curve where the difference in rates of the two grades is 0.3% or less.

Yours truly,

M. H. Brinkley,
Asst. Engr. G. N. Ry.

Seattle, Wash., Dec. 4, 1906.

The Meaning of "Average Haul" in Specifications.

Sir: In answer to the question of W. A. W. and B. C. in Engineering News of Dec. 6th, as to the interpretation of the specification: "When the average haul exceeds 500 ft. one cent per cubic yard will be paid for each 100 feet of excess haul," I should say that a fuller explanation of the conditions would make it easier to reach a decision that would give justice to the contractor, as well as protect the railway.

On irrigation work in the West it is customary to separate the overhaul of each section of cut and to measure from the center of gravity of that part of the cut that is overhauled to the center of gravity of the fill. It is presupposed that the excess cut in the canal is of such size as to warrant figuring the overhaul.

In the same way if the cuts of W. A. W. and B. C. are individually large enough, they should be considered separately.

There might be a case, however, where the line would run from small cuts to small fills every few stations, as in the rolling prairies in some parts of the West. Here the quantities might be so small that the center of gravity of all the cuts might have to be considered with the center of gravity of all the fills.

I think the word "average" will be generally considered to mean the average distance over which the number of yards in each individual cut are hauled, but there might be a case where the cuts and fills, being small, were so intimately mixed that the figuring of each cut separately would entail too much work.

Very truly, Henry A. Young.

Secretaria de Obras Publicas, Havana, Cuba, Dec. 18, 1906.

Earthwork Computations and Vertical Curves.

Sir: At various times lately articles have appeared relative to short cuts in earthwork computations, but as far as I recollect the writers always seem to average the end areas and then multiply by the distance between them. It is easier to average the distances than the areas. Thus—suppose we have areas A, B, C, D, etc., and that the distance from A to B is S_1 from B to C is S_2, from C to D is S_3, etc. Then the volume in cubic feet between A and D will be,

$$A \times \frac{S}{2} + B \times \frac{S + S_1}{2} + C \times \frac{S_1 + S_2}{2} + D \times \frac{S_2}{2}.$$

In other words, multiply each area by one-half the distance between the preceding and the following areas. In reducing to cubic yards, it seems to me that dividing by 27 is as easy as any other way to one who does much of this work, as the multiples of 27 up to 9 are easily memorized, and then the process is simply one in short division.

Regarding the inquiry of H. G. Cowling as to the best method for vertical curves, what method is better than regarding a vertical curve exactly the same as a horizontal curve excepting that instead of degrees of central angle, we have the algebraic sum of the rates of grade. Thus, suppose we have an ascending grade of 1% meeting a descending grade of 0.6% at Sta. 100, and we wish to put in a vertical curve 200 ft. each way from the summit, and wish the grade elevations at each 50-ft. point.

Algebraic sum of rates of grade = 0.80 (figuring on 50-ft. chords). For tangential deflection, divide by twice the length of curve in chords, in this case $\frac{0.80}{2 \times 8} = 0.05$.

Then the rates of grade per chord beginning with the tangent are as follows:

On tangent.....	+ 0.50	On curve.....	+ 0.05
On curve.....	+ 0.45	On curve.....	− 0.05
On curve.....	+ 0.35	On curve.....	− 0.15
On curve.....	+ 0.25	On curve.....	− 0.25
On curve.....	+ 0.15	On tangent.....	− 0.30

Thus the process proves itself. The grade elevations are then easily obtained by a continuous addition of the rates. Thus if elevation of beginning of curve is 98.00 the grades of the 50-ft. points are as follows:

	Grade.		Grade.
Sta. 98.....	98.00	Sta. + 50.....	99.25
Sta. + 50.....	98.45	Sta. 101.....	99.20
Sta. 99.....	98.80	Sta. + 50.....	99.05
Sta. + 50.....	99.05	Sta. 102.....	98.80
Sta. 100.....	99.20		

The advantage of this method is that no formulas of any kind need be remembered, merely the principle, which is practically the same as that of running horizontal curves. It is perfectly general.

Respectfully, H. F. S.

Cincinnati, Ohio, Nov. 24, 1906.

"The Lesson from Recent Failures of Reinforced Concrete Structures."

Sir: Engineers and the public generally are greatly indebted to you for the publication in a recent issue of your editorial entitled "The Lesson From the Recent Failures of Reinforced Concrete Structures." There is no doubt that much good has already been done by this article, and the reputation of Engineering News cannot fail to be still further enhanced by the firm attitude you have taken on the question discussed.

That your article will go a long way toward eradicating abuses prevalent in reinforced concrete construction has already been shown by the change of attitude on the part of one important concrete steel company. In a booklet published early this year this company said "the * * * system of reinforced concrete is sufficiently simple to permit of its use by the ordinary everyday contractor *without previous experience in reinforced concrete work.*" This was published before the Bixby Hotel and the Rochester collapses, and, of course, before the appearance of your article. Now the company referred to, I note, has changed the wording of its advertising matter to the following: "Perfect safety *when in the hands of expert men exercising care in handling the details and giving proper attention to the requirements of the design.*"

Evidently at least one concern has taken very much to heart the lesson of recent concrete collapses and the moral that you drew therefrom. Everyone, I believe, must admit that in calling for a halt in reckless and inexperienced concrete construction you have taken the only stand by which the reputation of the concrete building industry can be rehabilitated. Yours truly,

D. T. Pierce.

29 Broad St., New York City, Dec. 20, 1906.

Sir: I have been much interested in reading the various letters appearing in the recent numbers of your magazine apropos of the "Hotel Bixby" disaster, written largely by disinterested parties, and have been somewhat surprised that no one has ever touched on what seems to me the key to the whole danger in the use of reinforced concrete construction. I refer to the peculiar position of the "contracting engineer" in most of the recorded failures of this type of construction. Where the contracting engineer, who acts both as designer and builder of the work (or salesman of some essential part of the design) bids on work in competition with other parties in the same commercial field, the tendency will always be toward too large a proportion of the energy of such contractor being expended on "getting the work" and a constant working toward economies that would not always look advisable to an engineer whose sole interest was in designing a stable structure at as reasonable an expenditure to his client as good judgment might dictate.

The "contracting engineer" above referred to will constantly work toward the use of essential features of his "system" regardless of its adaptability to the particular situation. A disinterested engineer is free to vary his design to meet the required condition. The only reason for the "contracting engineer" in this field is that the dishonest architect is permitted by his use to avoid the expense of the employment of a competent engineer.

I consider the "contracting engineer" the dangerous feature of reinforced concrete construction.

Yours truly, Geo. S. Mills, Architect.

Gardner Bldg., Toledo, O., Dec. 21, 1906.

[The situation above described was one of our reasons for writing the editorial on reinforced-concrete work, published in our issue of Nov. 29,

*It is a rather remarkable fact that Mr. Moncrieff, in the paper already quoted, concluded that the factor $e c/r^2$ may be assumed to be a constant, just as in the flat-rate stress proposal. He recognized, however, that the factor has an "upper limit" and a "lower limit," for which he suggests the values 0.6 and 0.15, respectively. These would give the following equivalent eccentricities:

Upper limit, $e = 0.6 \frac{r}{c} r$, or for box section, $e = 0.48\, r$.

Lower limit, $e = 0.15 \frac{r}{c} r$, or for box section, $e = 0.12\, r$.

1906), under the heading which appears over this letter.—Ed.]

Sir: The writer read with much interest the editorial in your issue of Nov. 28, relative to failures in reinforced concrete construction. Speaking from extended experience in reinforced concrete work he can say that the indictment which you framed applies to much of the practice at present. Ignorant and bull-headed contractors are putting in work that is absolutely hazardous. The writer has met many of this type who seem to believe that once steel is added to concrete, it matters little how the work is done. The magic rod of steel is expected to bind together a mass of inert materials into a solid substance of wonderful strength!

It is high time that measures were taken to protect the future of this wonderful building material—there is admittedly no better if properly installed. But just as scrupulous care and inspection are necessary as in structural steel. The mix must be properly balanced and carefully watched to prevent batches getting in without their due proportion of cement. The reinforcement must be carefully placed and inspected by a competent man who knows where every bar goes and why it goes there—this notwithstanding widely advertised allegations to the contrary in regard to certain systems. In slabs—especially those in which hollow tile are incorporated—the top coat of cement must be applied at the same time that the concrete beams between the tiles are made, or else this top layer cannot be considered in figuring their strength. Here again skilled superintendence is essential. It is not a matter of time so much—it is a matter of correct and safe construction and of human life!

Finally, careful attention must be given the centering. It is essential that a daily record be kept of every piece of concrete placed and the forms should not be allowed to be removed until it is deemed safe by one competent to judge. The writer has seen workmen—uninstructed maybe—removing centers three or four days after the placing of concrete. Sometimes the structure holds—sometimes it falls.

There is another phase of the situation which deserves attention. Most of the concrete-steel companies to-day have a patent-bar to sell, and at the same time make their own designs. The temptation in this arrangement is obvious. To obviate the evils that are bound to be attendant on any combination like this, the engineering and commercial side must be separated.

Yours very truly,

O. D. C.

Chicago, Ill., Dec. 13, 1906.

The Design of Reinforced-Concrete Chimneys.

Sir: In making some calculations of reinforced-concrete chimneys, I have been at a loss to find any satisfactory working methods of determining dimensions or stresses. I have developed the following approximate formulas, which I give to you as they may be of use to some of your readers. I would be pleased to get in return from either you or your readers further light on the subject.

Assume the chimney ring to be concentrated into a circle of radius R equal to the radius of the middle of the concrete ring; assume the steel to be concentrated in a shell of thickness equal to s; call the thickness of the concrete ring c. Assuming the modulus of elasticity of the concrete does not vary within the limits of the working stresses, call

$$\frac{\text{E for steel}}{\text{E for concrete}} = m$$

And if T is the maximum stress in steel in tension, P the maximum compression stress in the concrete, call

$$\frac{T}{P} = n.$$

From the figure herewith,

$$n = \frac{b}{a} m$$

where b and a are the distances of the neutral axis from the tension and compression sides, respectively. If e denote the eccentricity of the neutral axis

$$e = R - a = b - R = \tfrac{1}{2}(b - a)$$

and if we set $k = e/R$, then

$$k = \frac{e}{R} = \frac{b-a}{(b+a)} = \frac{n-m}{n+m}.$$

Calling t the intensity of stress in the steel at any point whose coordinates are x and y,

$$t = \frac{T(y+e)}{R+e}$$

and the increment of total tension is

$$dF_t = t\,s\,dl = T\,\frac{y+e}{R+e}\,s\,R\,d\phi = \frac{T\,s\,R}{R+e}(R\sin\phi + e)\,d\phi.$$

Integrating between limits 0 and π gives for the total tension in the semicircle on the tension side

$$F_t' = \frac{T\,s\,R}{R+e}(2R + \pi e)$$

To this must be added the tension in the small arcs between center line and neutral axis. Taking these arcs to be straight lines their total tension is

$$F_t'' = \frac{T\,s\,e^2}{R+e}$$

which makes the total tension

$$F_t = F_t' + F_t'' = \frac{T\,s}{R+e}(e^2 + 2R^2 + \pi e R)$$

or, substituting $e = kR$,

$$F_t = \frac{T\,s\,R}{1+k}(2 + \pi k + k^2).$$

Similarly the total compression in the concrete of the compression side is found to be

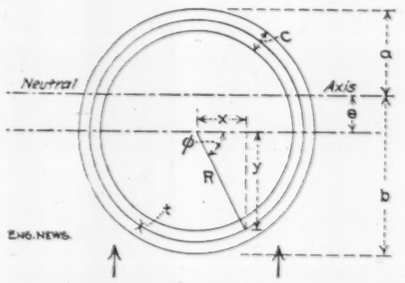
$$F_{c1} = \frac{P\,c\,R}{1-k}(2 - \pi k + k^2)$$

and the total compression in the steel of the compression side is

$$F_{c2} = \frac{m\,P\,s\,R}{1-k}(2 - \pi k + k^2)$$

so that the total compression is

$$F_c = \frac{P\,R}{1-k}(c + m\,s)(2 - \pi k + k^2).$$



The Reinforced Concrete Chimney.

Since the total compression must equal the total tension, $F_t = F_c$ or

$$\frac{P\,R}{1-k}(c + m\,s)(2 - \pi k + k^2) = \frac{T\,s\,R}{1+k}(2 + \pi k + k^2)$$

Solving this equation for $\frac{s}{c}$ to get the required amount of reinforcement for given maximum stresses in the two materials,

$$\frac{s}{c} = \frac{6.14\,m^2 - 0.14\,n^2 + 2\,m\,n}{6.28\,m\,(n^2 - m^2)}$$

To determine the moment of inertia of the combined section above the neutral axis:

The moment of inertia of the semicircle referred to the neutral axis

$$= \pi R\,(c + m\,s)\left(\frac{R^2}{2} - e^2\right).$$

The moment of inertia of the arcs e, taken as straight lines

$$= \frac{2(c + m\,s)\,e^3}{3}.$$

Total moment of inertia above the neutral axis

$$= \pi\,R\,(c + m\,s)\left(\frac{R^2}{2} - e^2\right) - \frac{2(c + m\,s)e^3}{3}.$$

Similarly, for steel below the neutral axis, equivalent in concrete moment of inertia

$$= \pi\,R\,m\,s\left(\frac{R^2}{2} + e^2\right) + \frac{2\,m\,s\,e^3}{3}.$$

The total moment of inertia, figured to concrete is

$$K = R^3 c\left[(1.57 - 3.14k^2 - .67k^3) + 3.14\,m\,\frac{s}{c}\right].$$

The necessary equations for calculating stresses in a chimney of given size and for determining the steel are

$$k = \frac{n-m}{n+m} \quad \ldots\ldots(A)$$

$$\frac{s}{c} = \frac{6.14\,m^2 - .14\,n^2 + 2\,m\,n}{6.28\,m\,(n^2 - m^2)} \quad \ldots\ldots(B)$$

$$K = R^3 c\left(1.57 - 3.14\,k^2 - .67\,k^3 + 3.14\,m\,\frac{s}{c}\right) \ldots(C)$$

To these may be added the bending moment

$$M = \frac{P\,c\,R^2}{1-k}\left(1.57 - 3.14\,k^2 - .67\,k^3 + 3.14\,m\,\frac{s}{c}\right) \ldots(D)$$

Yours very truly,

Charles B. Buerger.

Philadelphia, Pa., Nov. 26, 1906.

[The above calculation involves the tacit assumption that the vertical chimney resists lateral forces in exactly the same way that a horizontal (cantilever) beam resists vertical forces. That is to say, the assumption is that the windward side is actually in tension, so that, following common practice, the contributory resistance of the concrete on the tension side may be neglected. But in the chimney the existence of initial compressive stress, due to the weight of the structure, radically alters the case and destroys the similarity. The "tensile" component of the bending stress will manifest itself only as a reduction of the initial compression, while on the leeward side the "compression" component appears as an increase of the initial compression. Under these circumstances the windward and leeward segments behave in the same manner; the concrete and steel share in the stress proportionately to their compression moduli of elasticities. Evidently, then, the section is in fact a symmetrical one as regards resistance to the bending moment imposed by lateral wind pressure. Therefore, using our correspondent's symbols,

$$k = o \quad \ldots\ldots(A)$$

$\frac{s}{c}$ is indeterminate, or rather fixed only by constructional considerations. . . . . (B)

$$K_e = \pi\,R^3 c\left(1 + \frac{m\,s}{c}\right) \quad \ldots\ldots(C)$$

$$\text{and } M = \frac{K_e\,c}{R} = P\,\pi\,R^2 c\left(1 + \frac{m\,s}{c}\right) \quad \ldots\ldots(D)$$

Of course, the design may be such that the maximum wind pressure overcomes the initial compression on the windward side, which means that the resultant base pressure goes outside of the middle fourth and in a loose masonry chimney the windward joints would begin to open. For such a condition further study is necessary. If the concreting of the chimney is done in such a manner as to ensure the absence of transverse planes of separation, then we may fairly attribute a small amount of tensile strength to the concrete. As the resultant tension on the windward side will not be large in any case, it may be assumed that the concrete on the tension side shares the stress with the steel, just as does the concrete on the compression side. On this view the section is still to be calculated as a symmetrical one, to which the revised formulas we have given above must be applied. On the other hand, if there are likely to be horizontal planes of separation in the concrete, or if the chimney is of such unusual proportions that the tension due to wind greatly exceeds the initial compressive stress, then the course of analysis used by our correspondent will apply; not, however, to the total wind moment, but only to the excess of actual wind moment over the moment required to produce the limiting condition on the tension side.—Ed.]

Notes and Queries.

J. W. R., Buenos Aires, writes:

The price of lumber has gone up here.

Can you suggest something in place of it for making molds for reinforced concrete, galvanized or corrugated iron, or something similar?

The problem is one over which many engineers are puzzling; but sheet-iron or steel in any form is likely to prove too expensive. The most hopeful direction seems to be in providing forms which can be used over and over again and in substituting hollow block construction for all curtain walls.

A BOND FOR JOINING NEW CONCRETE TO OLD.

With the idea of obviating the difficulty now found in bonding together new and old concrete, Mr. H. S. Livingston* has invented a patent cement bond. This bond consists of an extract of coal tar, used instead of water as the mixing agent for neat Portland cement. The mixture is laid in ⅛-in. to ¼-in. layers on the old concrete surface and immediately followed by new concrete or mortar. The inventor claims the compound to be entirely insoluble and to form a complete and monolithic bond between the old and new works. It is furnished to customers free, they paying the freight and cost of barrels, the cost being covered by a certain royalty per square foot paid to the patentee of the process.

*306 East Lexington St., Baltimore, Md.

THE UNITED ENGINEERING SOCIETY BUILDING.

The United Engineering Society Building at 29 West 39th St., New York City, which has been in course of construction for somewhat over a year, is now finished and ready for occupancy. Although built especially for the American Institute of Mining Engineers, the American Society of Mechanical Engineers, and the American Institute of Electrical Engineers, the first two of whom have already moved in, the building will accommodate a number of other engineering societies.

The societies definitely provided for in addition to the three just mentioned are the Society of Naval Architects and Marine Engineers, the Illuminating Engineering Society, the National Electric Light Association, the Underwriters' Laboratory of the National Protective Association, the Association of Edison Illuminating Companies, the American Street and Interurban Railway Association, and the New York Electrical Society.

It is expected that the following societies will also have quarters in the building: Municipal Engineers of the City of New York, the New York State Association of Stationary Engineers, the American Gas Light Association, and the Empire State Gas and Electric Association. In addition, there are a number of societies which will hold meetings in the building but will have no executive offices there. Two floors have been reserved for these societies, among which are the American Society of Heating and Ventilating Engineers, the American Foundrymen's Association, the American Society of Refrigerating Engineers, the Technical Society of New York, the American Society of Swedish Engineers, and the American Society of Automobile Engineers.

The available space in the building suitable for offices, meeting rooms, etc., but not yet engaged, amounts to about 15 rooms. Of these, the mining, mechanical, and electrical societies each have three rooms to let.

Our readers have already been informed* of the requirements of the building and of the necessary construction and planning of the different floors to meet these requirements. As the architects' original plans have been followed with practically no deviations, there is little to be added to what has already been given on this subject. The working out of the plans, however, have introduced several unusual features which are worthy of note.

The most striking of these features is the means employed for supporting the eight stories and their respective loads above the auditorium, which occupies nearly the entire area of the building, without placing columns in the auditorium. The chief objection to the columns, of course, was the obstruction they offered to a view of the stage from certain seats in the orchestra and gallery. The matter was rendered especially complicated by the location of the library on the top floor, where allowance had to be made for the weight of 300,000 books. In place of columns, steel girders of enormous size and weight were therefore used. Over the auditorium there are two 60-ton plate girders made up of three 20-ton girders in parallel, and at each end of the auditorium there is one 40-ton plate girder.

Above the assembly rooms on the fifth floor there is a lattice girder which weighs 60 tons. The two columns which extend up to the bottom of this lattice girder through a distance of 40 ft. weigh 1,000 lbs. per ft.

The foundations were carried down to an average depth of 37 ft.; in some cases a hard rock footing was secured at a depth of 27 ft., but in other cases it was necessary to go down 67 ft. before good rock was found. As two of the column footings have to sustain a weight of structure amounting to 3,000,000 lbs. each, and the weight of 1,000 lbs. per ft. of length of the columns, the matter of substantial foundations was an important consideration. About 13,000 cu. yds. of earth had to be excavated and over 1,600 cu. yds. of concrete used in building up the footings.

A VIEW OF THE UNITED ENGINEERING SOCIETY BUILDING, 29 WEST 39TH STREET, NEW YORK CITY, TAKEN SHORTLY BEFORE THE BUILDING WAS FINISHED.

Hale & Rogers, Architects; Wells Bros. Co., Contractors.

The floors throughout the building are of fireproof material except in the lecture rooms, where wooden floors are used. The first floor is of granite, the second, third and fourth of limestone, and those above the fourth floor, with the exception of the lecture rooms, are of cinder-concrete laid over terra cotta arches. Additional fire protection is afforded by metal-lathe ceiling suspended 2 ins. below the floor beams. The window frames and cases are either metal or metal covered, and wire glass is used in exposed windows up to 100 ft. above ground and for the elevator-grills.

The stage platforms in the auditorium and assembly rooms are equipped with pipes for hot and cold water and for compressed air; also with electrical circuits for high and low pressure currents to be used in demonstration work. Exhaust hoods are provided on the stage for carrying off offensive odors in chemical work. In the auditorium an electric projection lantern and screen are permanent attachments. Seats are permanently installed for 1,000 persons, although 1,200 can be accommodated if necessary.

The building is lighted throughout with electricity. Between 4,000 and 4,500 incandescent lamps are used; those employed for lighting the auditorium are controlled by dimmers. In both the auditorium and assembly rooms the lamps are concealed, and the light being reflected by the walls and ceilings into the rooms gives an excellent diffused illumination. In the offices the ceilings are paneled with electric-wire molding so designed that lamps can be tapped in at any desired point. The air supply for the auditorium and assembly halls amounts to about 100,000 cu. ft. per min., and the exhaust has a capacity of 90,000 cu. ft. per min.

An excellent idea of the imposing character of the building can be obtained from the accompanying illustration which, however, was taken before the structure was finished. The new building of the Engineers' Club may be seen at the rear, fronting on 40th St.

An unusual feature of the United Engineering Society Building is the treatment of the side walls so that they harmonize with the front of the building. All four sides are built of hydraulic-pressed gray mottled brick, with limestone and terra cotta trimmings. The height of the building from sidewalk to top of parapet is 220 ft.

The center door at the front leads to the main entrance hall or foyer through an attractive vestibule. The door to the right of the center one leads to a covered driveway by which access is had to the interior of the building on that side and to the passage at the north and west. The door to the left affords direct access to elevators and stairways leading to each of the floors of the building.

Among the many advantages incident to the coming together of the different societies in one building is the great engineering library formed by the combination of the respective libraries of the mining, mechanical, and electrical engineers. This will be conducted as a public library, with special privileges to society members. It will be ready for use by the latter part of February.

Provision having been made in the building whereby luncheons and suppers may conveniently be served, receptions can more readily be given than heretofore. There will also be ample room for exhibition purposes, and the conveniences provided for handling and erecting heavy machinery in the lecture halls are luxuries that have not hitherto been enjoyed.

These, and other advantages too numerous to mention, will greatly facilitate the work of the societies, and increase the value of membership therein.

*Engineering News, Dec. 14, 1905; p. 615.

ANNUAL MEETING OF THE AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE.

About a thousand scientists, representing nearly every college of importance in the United States, assembled at Columbia University Dec. 27, 1906, to Jan. 2, 1907, to attend the 57th meeting of the American Association for the Advancement of Science.

The Association is composed of ten different divisions dealing with mathematics and astronomy, physics, chemistry, mechanical science and engineering, geology and geography, zoology, botany, anthropology, social and economic science, and physiology and experimental medicine. With the association assembled 19 affiliated scientific societies.

The entire gathering was called to order shortly after 10 a. m. on the opening day by Dr. C. M. Woodward, the retiring President, who introduced Dr. W. H. Welch, of Johns Hopkins University, as his successor. Dr. Nicholas Murray Butler, President of Columbia University, then delivered an address of welcome. After the usual routine business had been transacted the respective divisions of the association retired to sectional meetings.

The division dealing with mechanical science and engineering was disappointing in a number of ways. The attendance was small, several of the papers on the list were not ready for presentation, and the majority of the papers presented called forth little or no discussion. The inference to be drawn is that the field of mechanical science and engineering is so well covered by other engineering societies that there is too much competition for this division of the association. Under the circumstances it would seem advisable to discontinue it.

Twelve papers were listed for presentation. These were: Polyphase Power Measurement, by Comfort A. Adams, Jr., Assistant Professor of Electrical Engineering, Harvard University, Cambridge, Mass.; Theory of Horizontal Compression Members with Eccentric Pin Connections, by James E. Boyd, Professor of Applied Mechanics, Ohio State University, Columbus, Ohio; Telephone Line Engineering, by C. J. H. Woodbury, of the American Telephone and Telegraph Co., Boston, Mass.; Science in the Foundry, by William W. Hearne, Philadelphia, Pa.; Piping and Segregation in Ingots, by Henry M. Howe, Professor of Mining Engineering, Columbia University, New York City, and by Bradley Stoughton, Columbia University; The Colorado River and Salton Sea Controlled, by Edgar L. Larkin, Director of Lowe Observatory, Echo Mountain, California; A Recent Determination of the Figure and Size of the Earth from Measurements in the United States, by John F. Hayford, U. S. Coast and Geodetic Survey, Washington, D. C.; The Recent Use of Nickel-Steel (Invar) Tapes in the Measurement of Primary Bases, by O. B. French and John F. Hayford, U. S. Coast and Geodetic Survey, Washington, D. C.; Experimental Research with the Air-Driven Hydrolisthan or Water-Glider, by David Todd, Observatory House, Amherst, Mass.; A New Electric Furnace, by W. H. Bristol, Stevens Institute; Tests of a Producer Gas Engine, by G. W. Bissell, Iowa State College; Some Observations on Water Purification, by P. A. Maignen, Philadelphia, Pa.

The President of this section, Prof. F. W. McNair, of the Michigan College of Mines, Houghton, Mich., delivered an address Friday morning, Dec. 28, on "Some Problems Connected with Deep Mining on Lake Superior." The entire program was finished and the section adjourned Friday afternoon.

Professors Adams and Boyd confined themselves very closely to the respective subjects of their papers. Mr. Woodbury, on the other hand, elaborated quite extensively on telephone line engineering. He said 55% of the telephone lines in the United States are now underground, 25% are in overhead cable form, and the remainder are overhead open-wire lines. He called attention to the damage caused to poles by woodpeckers and by the formation of ice on the wires, and also to the greater decay of poles in southern countries. Copper wire now costs about 20 cts. per lb., and as there is a difference of only 2 cts. per lb. between new wire and junk copper, it does not usually pay to untangle wires for further use on pole lines when they have become twisted by the poles breaking.

Mr. Hayford read the paper relating to Invar tapes for measuring primary bases. He claimed that tapes are superior to wires for such measurements and that nickel-steel or Invar tapes show the least change in length with changes in temperature of any material thus far used. Invar tapes, he said, have a coefficient of extension 1/38 that of steel and the error in measurement is but one-half that with steel tapes. They also enable measurements to be taken more rapidly, and the observer requires less previous training. He advised their standardization in Washington and not in the field.

Mr. Bristol illustrated his paper on electric furnaces with two working models. His new furnace is designed for riveting and other small work. It is also very convenient for demonstration work, developing a temperature of 1,400° F. in 1 min. after the electric circuit is closed. Temperatures up to 2,000° F. have been obtained in it. Dental furnaces require about 15 min. to heat up, so the advantage of the one described is obvious. The new furnace consists of a quartz crucible wound with platinum wire. Between the turns of the platinum wire is wound a thread of asbestos cord, and the whole is covered with refractory material. The quartz crucible allows changes of temperature within it and prevents the turns of wire from becoming short-circuited by the material introduced in the furnace.

Mr. Bissell's paper giving tests of a producer gas engine was read by Secretary W. T. Magruder, owing to the absence of the author. The engine, of the 3-cylinder single-acting type, was directly connected to a 75-KW., two-phase alternator. The tests were conducted with anthracite coal and gave the following results:

Brake Test.

Length of run.	Average B. HP.	Per cent. of rating.	Coal as fired per B. T. U.	Total eff. from coal.
6	40.1	26.8	1.51	15.69
7	82.5	55.0	1.15	17.56
6	156.9	104.2	0.99	19.09

Heat Balance at Full Load.

B. T. U. in coal as fired		100%
" " B. HP.	19.69%	
" " unburned coal in ash	11.46%	
" " radiation from producer	2.33%	
" " radiation from scrubber	.31%	
" " vaporizer	.65%	
" " scrubber water	7.15%	
" " jacket water	20.90%	
" " exhaust gases	31.75%	
" unaccounted for	5.76%	
	100.00%	

RAILWAY CONSTRUCTION IN 1906, in the United States, reached a total of 6,067 miles for 388 lines in 44 states and territories, according to the annual statistics of the "Railway Age." This is the highest amount since the 12,983 miles of 1887 and 7,106 miles of 1888. The nearest approach to it since those years was 5,786 miles in 1903. These figures include only the mileage upon which track was laid, and a much greater record would have been made in 1906, as over 13,000 miles were under contract as far back as March, but scarcity of men and difficulty in obtaining rails have seriously retarded the progress of work. The highest records are 701 miles in Texas, 391 in Louisiana, 389 in South Dakota and 360 miles in Nevada. At the bottom of the list comes Massachusetts with 4½ miles. About 973 miles of track were laid in Canada and 245 miles in Mexico.

A SERIOUS REAR COLLISION occurred at Terra Cotta, a suburb of Washington, D. C., on the night of Dec. 30, in which some 55 persons were killed and 60 injured, many seriously. A Baltimore & Ohio train, known as "The Frederick City (Md.) Local No. 66," was just leaving the station at Terra Cotta, when it was crashed into by a dead-head equipment train, made up of empty Pullman and day coaches. The "dead-head" train was drawn by one of the heaviest locomotives in the service of the company, and was running at high speed. The local train carried two day coaches and a smoker, all heavily loaded. The two day coaches were completely demolished, while the smoker was telescoped. The speed of the "dead-head" was so great that wreckage and dead and injured passengers were strewn along the track for a long distance. A block system of some sort appears to be in use on the road where the accident occurred, and there is conflict of accounts as to whether the signal operator or the engine runner was at fault. The accident occurred during a very thick fog, and the high speed at which the "dead-head" train was running makes it probable that its engineer took chances on seeing the signals correctly.

A RAILWAY COLLISION on the North British Ry. at Arbroath, Scotland, Dec. 28, killed 16 persons and injured 30 others. The accident is said to have been due indirectly to a heavy fall of snow. Trains for London from Aberdeen, Scotland, were held up at Arbroath on account of the snow but finally one train proceeded for Dundee, Scotland. It was stopped at Elliot Junction, however, and signals set, as supposed, against a following train. The signals however, failed to work, being clogged with snow and an express train crashed into the rear of the standing train.

A WRECK of an accommodation train on the Minneapolis St. Paul & Sault Ste. Marie R. R. at Enderlin, N. Dak., Dec. 23, killed nine persons and injured 31 others. The accommodation was running at high speed to make up lost time and as it entered the yards at Enderlin, struck a switch engine, which was switching freight cars. A sharp curve prevented either engineer seeing the other train in time to avert the collision. All the fatalities occurred in the smoking car, which was telescoped by the baggage car. Some of the day coaches were thrown down a small embankment but none of the sleeping cars left the track. The wreckage took fire but all the injured and dead were taken out before the fire reached them.

THE SCRANTON TYPHOID EPIDEMIC numbered 848 cases and 29 deaths up to noon on Dec. 31. The Elmhurst reservoir of the Scranton Gas & Water Co. was shut off on Saturday, Dec. 15, and as this is supposed to be the source of infection it is expected that primary cases will be much diminished in number by Saturday, Jan. 5. The local and state hospitals having been filled to overflowing an emergency hospital was opened on Jan. 1. Up to 8 p. m. of Jan. 1 a total of 897 cases and 39 deaths had been reported, according to press dispatches.

BIDS FOR A REFUSE DESTRUCTOR at West New Brighton, Richmond Borough, New York City, were opened on Dec. 27, as follows. Universal Destructor Co., 17 State St., New York City, $22,535; Heenan & Froude, 111 Broadway, New York City, $23,995; Decairie Manufacturing Co., Minneapolis, Minn., $18,600, $25,700 and $32,600, according to variations in plans submitted. The bids include the preparation of plans for the proposed destructor, building and accessories and also the construction of the furnaces and boiler, all as stated in detail in an illustrated article published in our issue of Dec. 6. The first of the bids was for a Meidrum and the second for a Heenan & Froude destructor, both well known British destructors. The award had not been made when we went to press.

A CHIMNEY 500 FT. HIGH will be built at the Boston & Montana smelter, Great Falls, Mont., to carry off the gases from the smelting furnaces; it will be the highest chimney in the world, as the highest at the present time is 460 ft., a chimney at Freiburg, Germany. The stack is designed to have an inside diameter at top of 50 ft., and an outside diameter at bottom of 75 ft. The location of the structure is 3,535 ft. above sea level. The chimney top will be 742 ft. above the charging floor of the furnaces. The Alphons Custodis Chimney Construction Co., of New York, N. Y., which has the contract for building the chimney, is putting up a brickyard near the site, for making the perforated radial brick of which the main shell will consist. The construction of the chimney is estimated to take a year's time, and will cost about $200,000, exclusive of the foundation. The total weight of the structure approximates 16,600 tons.

This chimney is designed to carry off per minute 4,000,000 cu. ft. of gases with a maximum temperature of 600° F. On account of the exposed location, and the prevalence of high winds, the design provides for a maximum wind of 125 mi. per hr. Further, the chimney may be built 60 ft. higher at a later time, if it should be found that more draft is needed. The gases which it is to handle are highly acid, consisting largely of sulphur dioxide, and this fact required full consideration, particularly as the present chimney at the works (188 by 20 ft.) is badly cracked from the action of the acid on the cement mortar. The new stack will have a 4-in. lining of acid-proof brick laid in acid-proof mortar, carried on corbels of the main wall every 20 to 30 ft. of height. The expansion space at the top of each such section will be packed with mineral wool to keep the flue-dust from settling in the air-space between lining and wall. A terra cotta cap laid in acid-proof mortar will cover the top of the stack. In the upper part of the outside face the joints are to be pointed with acid-proof mortar.

PERSONALS.

Mr. W. H. Willis has been appointed Signal Engineer of the Erie R. R., to succeed Mr. C. H. Morrison, resigned.

Mr. William H. White has been elected President of the Richmond, Fredericksburg & Potomac R. R., at a salary of $13,000 per year.

Mr. O. F. Wasmansdorff, City Engineer of Lewistown, Mont., has been elected county surveyor of Fergus County, Montana. He will retain both offices.

Mr. F. C. Borst has been appointed Chief Draftsman in the office of the mechanical engineer of the Denver & Rio Grande R. R., Burnham Station, Denver, Colo.

Mr. H. H. Thatcher, Private Secretary to Colonel E. L. Russell, Vice President of the Mobile & Ohio R. R., has been appointed Assistant Superintendent of the road.

Mr. W. H. Gatchell, Superintendent of the Nashville Division of the Southern Ry., has been appointed to

the newly-created position of Superintendent of Transfers of the whole system.

Mr. H. C. Carr, formerly Metallurgical Engineer with the Joshua Hendy Iron Works, has been appointed Superintendent of the Nevada Consolidated Mining and Milling Co., Wadsworth, Nev.

Mr. D. E. Cain, General Manager of the southwestern lines of the Chicago, Rock Island & Pacific Ry., has resigned to become Assistant Vice President, in charge of operation, of the Denver & Rio Grande R. R.

Mr. John H. Rankin has been appointed Superintendent of Materials and Supplies for the Philadelphia & Reading Ry., with office at Reading, Pa. This is a new office that has just been created. Mr. Rankin will have general supervision of all materials and supplies.

Mr. Bion J. Arnold, M. Am. Soc. C. E., has been appointed a member of the Board of Supervising Engineers for the city of Chicago. This board will superintend for the city the rehabilitation of Chicago's traction system. Mr. Arnold's salary will be $30,000 per year.

Mr. H. F. White, Engineer of Maintenance of the Chicago, Rock Island & Pacific Ry., has had his jurisdiction extended over all the lines of the Rock Island system, and Mr. J. G. Bloom, Engineer of Maintenance of the Western lines, has been assigned to other duties.

Mr. Asa M. Mattice, M. Am. Soc. M. E., Consulting Engineer, 60 Wall St., New York City, has accepted the management of the works of the Walworth Manufacturing Co., South Boston, Mass., and closed his consulting office Dec. 31. His address is in care of the above company.

Mr. F. S. Forrest, Superintendent of the Montana Central Division of the Great Northern Ry., has been appointed Assistant General Superintendent, to succeed Mr. J. M. Davis, resigned. Mr. P. C. Allen, formerly Superintendent of the Willmar & Sioux Falls Ry., will succeed Mr. Forrest.

Mr. J. E. Sewell has been appointed General Manager of Connecticut Railway & Lighting Co. These properties were lately acquired by the New York, New Haven & Hartford R. R., and will be operated under the title "Lessees Connecticut Railway and Lighting Co." Mr. Sewell's headquarters will be at Waterbury, Conn.

Mr. G. A. Stranahan, Assistant Engineer of the Southern Pacific Co., in charge of the location of a railway between the Fuerte River and Mazatlan in the State of Sinaloa, Mexico, has resigned and accepted a position with the State of Sinaloa to build a steel highway bridge across the Tamazula River at the City of Culiacan, the State capitol.

Mr. George M. Basford, head of the Publicity Department of the American Locomotive Co., has been promoted to Assistant to President W. H. Marshall, the position being a new one. Mr. Basford is a graduate of the Mechanical Engineering Department of the Massachusetts Institute of Technology. After being connected with the motive power departments of the Boston & Maine R. R., the Chicago, Burlington & Quincy R. R., and the Chicago, Milwaukee & St. Paul Ry., he became Editor of the "Railway and Engineering Review" of Chicago. In 1897 he removed to New York City and became Editor of the "American Engineer and Railroad Journal," and in September, 1905, accepted a position with the American Locomotive Co. to organize and conduct a publicity department.

Obituary.

Commander Alfred B. Canaga, in charge of the Steam Engineering Department of the Charlestown Navy Yard, died Dec. 24 of apoplexy. He was a native of Ohio and entered the service in 1872.

Benjamin Franklin Dutton, a retired contractor of Philadelphia, Pa., died at Atlantic City, N. J., Dec. 23, aged 90 years. He was a native of Harford County, Md., and a veteran of the Mexican War.

Frederick C. Schaffhauser, a civil engineer, employed by the Water Bureau of Philadelphia, died Dec. 25 from wounds received Nov. 9, when he was shot by Frederick Hornberger. Mr. Schaffhauser gained notoriety in the trial of former Chief John W. Hill of the Filtration Bureau for fraud, he being the chief witness for the city.

O. D. Richards, Chief Engineer of the Ann Arbor R. R. and the Detroit, Toledo & Ironton Ry., died at his home in Toledo, O., Dec. 20, of pneumonia, aged 63 years. Before entering the employ of the Ann Arbor road, Mr. Richards was employed, some 20 years, in the engineering department of the Lake Shore & Michigan Southern Ry.

Ernest Fasy, a civil engineer, died at Tuscaloosa, Ala., Dec. 23. He was born at Zurich, Switzerland, and was a graduate of the University of Zurich. During the Franco-Prussian War he served as First Lieutenant of Engineers. He came to America about 1873 and had done considerable work at Chattanooga, Tenn., Mobile and Tuscaloosa, Ala., and Havana, Cuba. At the time of his death he was employed by Woolsey Finnell, Civil Engineer, Tuscaloosa, Ala.

Adolf Goering, for many years Professor of Railway Engineering at the Berlin Technical College, died in Berlin, Germany, a few weeks ago. He was born in 1841, studied engineering at Hanover and Berlin, and was active in railway work on state and private railways for a number of years. In 1877 he entered the faculty of the Berlin Bau-Akademie, and later was called to the Berlin Technical College. The scientific planning of railway terminals and yards was originated by Goering. He was author of a book on earthwork calculation, and of the sections on railway construction in the standard German pocketbook "Hütte."

Alexander Johnston Cassatt, President of the Pennsylvania Railroad system, died at his home in Philadelphia, Pa., Dec. 28, of heart disease, aged 67 years. He was born at Pittsburg, Pa., Dec. 8, 1839, and received his early education in the schools of Pittsburg and Europe. While abroad he also studied at the University of Darmstadt and upon his return to the United States entered Rensselaer Polytechnic Institute, graduating as a civil engineer with the class of '59. He immediately accepted a position on the construction staff of a railroad in Georgia, where he remained for two years. In 1861 he was appointed a rodman on the Philadelphia Division of the Pennsylvania R. R., and two years later was assigned to the engineering corps, engaged in constructing a road connecting the Pennsylvania R. R. and the Philadelphia & Trenton R. R., as an assistant engineer.

When the Pennsylvania company assumed control of the Philadelphia & Erie R. R. in 1864, Mr. Cassatt was transferred to Renovo, Pa., and made Resident Engineer of the Middle Division of the road. In April, 1866, he was transferred to Williamsport, Pa., and given the position of Superintendent of Motive Power and Machinery of the Philadelphia & Erie R. R. He was appointed to a like position on the Pennsylvania R. R. in November, 1867, with headquarters at Altoona, Pa. Upon the resignation of Dr. Edward H. Williams as General Superintendent of the Pennsylvania R. R., April 1, 1870, Mr. Cassatt was elected to succeed him. In 1871 he was made General Manager of all Pennsylvania lines east of Pittsburg and Erie.

On July 1, 1874, Mr. Cassatt was elected Third Vice President of the Pennsylvania R. R., which position he filled until June 1, 1880, when he was advanced to First Vice President. He voluntarily resigned this office Sept. 30, 1882, and retired to private life. On Sept. 12, 1883, he was elected a director of the Pennsylvania R. R. From February 17, 1885, to June 14, 1899, he filled the position of President of the New York, Philadelphia & Norfolk R. R. He was elected President of the Pennsylvania R. R. June 9, 1899, and shortly thereafter, President of the Philadelphia, Willmington & Baltimore R. R., the Northern Central Ry., the Pennsylvania Co. and the Pittsburg, Cincinnati, Chicago & St. Louis Ry.

Upon his accession to the presidency of the Pennsylvania system, Mr. Cassatt recommended to the Board of Directors comprehensive improvements for the whole system. Among these improvements was a New York City station necessitating tunnels under the North and East Rivers, the connecting at Long Island City of the Pennsylvania road and the New York, New Haven & Hartford R. R., the building of many miles of new track to reduce grades and straighten curves, a new station and yards at Washington, D. C., etc. Many of these improvements are now well advanced and eventually all will be completed. While President, Mr. Cassatt instituted many reforms, doing away with passes, rebates, etc., besides causing changes in the policy of the company, whereby both employees and the public were benefited.

ENGINEERING SOCIETIES.

COMING MEETINGS.

ENGINEERS' SOCIETY OF WESTERN PENNSYLVANIA.
Jan. 3. Annual Meeting at Pittsburg, Pa. Secy., F. V. McMullin, 410 Pennsylvania Ave., Pittsburg, Pa.

THE AMERICAN INSTITUTE OF ARCHITECTS.
Jan. 7-9. Annual Convention at Washington, D. C., Secy., Glenn Brown, Washington, D. C.

MICHIGAN ENGINEERING SOCIETY.
Jan. 8. Annual Convention at Detroit, Mich. Secy., F. Hodgman, Climax, Mich.

NATIONAL ASSOCIATION OF CEMENT USERS.
Jan. 8-11. Annual Meeting at Chicago, Ill. Secy., W. W. Curtis, 585 Caxton Bldg., Chicago, Ill.

NEW ENGLAND WATER-WORKS ASSOCIATION.
Jan. 9. Annual Meeting at Boston, Mass. Secy., Mr. Willard Kent, Narragansett Pier, R. I.

IOWA ENGINEERING SOCIETY.
Jan. 9-11. Annual convention at Ottumwa, Ia. Secy., A. W. Ford, Iowa City, Ia.

WOOD PRESERVERS' ASSOCIATION.
Jan. 15. Annual Meeting at Memphis, Tenn. Secy., C. W. Berry, Laramie, Wyo.

AMERICAN SOCIETY OF CIVIL ENGINEERS.
Jan. 16-17. Annual Meeting at New York City. Secy., C. W. Hunt, 220 West 57th St., New York.

NORTHWESTERN CEMENT PRODUCTS ASSOCIATION.
Jan. 16-18. Annual Convention at St. Paul, Minn. Secy., Martin T. Roche, 410 Pioneer Press Bldg., St. Paul, Minn.

INDIANA ENGINEERING SOCIETY.
Jan. 17-19. Annual Meeting at Indianapolis. Secy., C. C. Brown, Commercial Club Building, Indianapolis, Ind.

THE ENGINEERS' CLUB OF PHILADELPHIA.
Jan. 19. Annual Meeting at Philadelphia. Secy., Walter Loring Webb, 1122 Girard St., Philadelphia, Pa.

AMERICAN SOCIETY OF HEATING AND VENTILATING ENGINEERS.
Jan. 22-24. Annual Meeting at New York City. Secy., W. M. Mackay, P. O. Box 1818, New York City.

OHIO ENGINEERING SOCIETY.
Jan. 22-24. Annual convention at Columbus, Ohio. Secy., E. G. Bradbury, 85 North High St., Columbus, Ohio.

ILLINOIS SOCIETY OF ENGINEERS AND SURVEYORS.
Jan. 23-25. Annual Meeting at Peoria, Ill. Secy., E. E. R. Tratman, 1636 Monadnock Block, Chicago, Ill.

CANADIAN SOCIETY OF CIVIL ENGINEERS.
Jan. 29. Annual Meeting at Montreal. Secy., Prof. C. H. McLeod, 877 Dorchester St., Montreal, Quebec.

THE NATIONAL BRICK MANUFACTURERS' ASSOCIATION.
Feb. 4-16. National Convention at St. Louis, Mo. Secy., Theo. A. Randall, Indianapolis, Ind.

NEW ENGLAND GAS ASSOCIATION.
Feb. 21. Annual Meeting at Boston, Mass. Secy., N. W. Gifford, East Boston, Mass.

ASSOCIATION OF ONTARIO LAND SURVEYORS.
Feb. 26. Annual Meeting at Toronto. Secy., Killaly Gamble, 405 Temple Bldg., Toronto, Ont.

AMERICAN RAILWAY ENGINEERING AND MAINTENANCE OF WAY ASSOCIATION.
Mar. 19-21. Annual Meeting at Chicago, Ill. Secy., L. C. Fritch, 1562 Monadnock Block, Chicago, Ill.

AMERICAN SOCIETY OF MECHANICAL ENGINEERS.—The next meeting of the society will be held in the auditorium of the new Engineering Building, Jan. 8. This will be the first time that the new hall will have been used. The address of the evening will be given by Mr. F. P. Fish, President of the American Telephone and Telegraph Co., his subject being "The Ethics of the Secret Process Versus the Patent System."

NEW ENGLAND WATER WORKS ASSOCIATION.—The annual meeting of the association will be held at Hotel Brunswick, Copley Square, Boston, Mass., Jan. 9. A business session will be held at 2 o'clock, when the reports of the Secretary, Treasurer, Tellers of Election and other officers will be read, and the annual address of the President given. The papers to be presented are "Meter Registration," by Mr. Arthur N. French, and "Sanitary Protection of Water Sheds," by Mr. William W. Locke. All persons in attendance are requested to be sure and register.

AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS.—The 212th meeting was held in the assembly room of the New York Edison Co., 44 West 27th St., New York City, Friday evening, Dec. 28, 1906. About 175 were in attendance. Secretary Pope announced that 44 associate members had been elected at the afternoon meeting and that there were yet 150 applicants on the waiting list. He also read an invitation to the members to attend the meeting of the American Society of Mechanical Engineers on Jan. 8 in the new engineering building on 39th St., this being the first regular meeting to be held there. Mr. F. P. Fish will discuss the ethics of trade secrets in relation to the patent system at this meeting.

Following Secretary Pope's announcement, President Sheldon introduced Mr. R. P. Jackson, Electrical Engineer of the Westinghouse Electric & Manufacturing Co., Pittsburg, Pa., who presented a paper, entitled "Recent Investigations of Lightning Protective Apparatus." This paper outlined the characteristics of lightning as manifested on electric circuits and gave results of recent investigations as to the characteristics lightning protective devices should possess to render them most effective. The author illustrated the effect of lightning on transformers and generators by comparing it to the effect produced in cases of impact of surges in an elastic fluid like a heavy gas, enclosed in a pipe. He then considered different kinds of lightning protective apparatus: arc-suppressing devices, gap and fuse arresters, and electrolytic arresters. The general treatment of the subject was excellent, but the figures given showing the results of investigations made in the Westinghouse Works were for special cases only and were therefore of little value. The paper was discussed by Mr. Ralph D. Mershon, Mr. Charles P. Steinmetz, Mr. Percy H. Thomas, Mr. Harold W. Buck, and Mr. H. B. Alverson. Mr. Mershon was skeptical as to the value of laboratory experiments with lightning arresters on account of the impossibility of reproducing lightning discharges as they occur in nature. He advised either doing away with choke coils altogether or else enclosing them in the same case with the transformer. He believed that much of the apparatus now installed within a station would in the future be located out of doors. Lightning protective apparatus, bus bars, and circuit breakers, he thought, should be constructed with this idea in view. Mr. Steinmetz agreed with the author of the paper that the series resistance of an arrester should be very low, and in fact suggested doing away with it altogether. He took exceptions to the numerical values given by Mr. Jackson and explained his reasons for doubting them. The rest of the speakers dwelt largely upon the electrolytic arrester, agreeing with the author of the paper that the electrical characteristics of this device seem to be ideal for lightning protection.